Fishery Data Series No. 17-32

Sonar Estimation of Salmon Passage in the Yukon River near Pilot Station, 2015

by

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July 2017

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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by
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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

ABSTRACT

The Pilot Station sonar project has provided daily passage estimates for Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), and coho (*O. kisutch*) salmon for most years since 1986. Fish passage estimates for each species were generated in 2015 through a 2-component process: (1) estimation of total fish passage with 120 kHz split-beam sonar and an adaptive resolution imaging sonar, and (2) apportionment to species by sampling with a suite of gillnets of various mesh sizes. An estimated 3,422,703 fish passed through the sonar sampling area between May 31 and August 31. Of those fish, 1,041,464 passed along the right bank and 2,381,239 passed along the left bank. Included, with 90% confidence intervals, were 86,620 ± 23,678 large Chinook salmon (>655 mm mid eye to tail fork), 29,464 ± 18,465 small Chinook salmon (≤655 mm mid eye to tail fork), 1,385,083 ± 103,203 summer chum salmon, 546,894 ± 44,039 fall chum salmon, 97,587 ± 15,280 coho salmon, 22,421 ± 11,817 pink salmon, and 1,254,634 ± 90,067 other species.

Key words: Chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, coho salmon *O. kisutch*, ARIS adaptive resolution imaging sonar, hydroacoustic, split-beam sonar, riverine, sonar, run strength, species apportionment, net selectivity, Yukon River

INTRODUCTION

BACKGROUND

In Alaska, Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), and coho (*O. kisutch*) salmon are managed inseason for harvest by commercial, subsistence, and sport fisheries within the Alaska portion of the Yukon River drainage, as well as to meet treaty obligations made under the U.S./Canada Yukon River Salmon Agreement. The diversity and number of fish stocks, combined with the geographic range of user groups, adds complexity to management decisions. Escapement estimates and run-strength indices are generated by various projects within the drainage, providing stock-specific abundance and timing information; however, much of this information is obtained after the fish have become unavailable to the fisheries. Timely indices of run strength are provided by gillnet test fisheries conducted in the Lower Yukon River, but the functional relationship between catch per unit effort (CPUE) and actual abundance is confounded by varying migration patterns through the multi-channel environment, gear selectivity, environmental conditions, and changes in net site characteristics.

The Pilot Station sonar project has provided daily salmon passage estimates, run timing, and biological information to fisheries managers for most years since 1986. The project is located at river km 197 in a single channel environment near the village of Pilot Station. This location is upriver enough to avoid the multiple channel environment of the Yukon River Delta. The project is able to provide timely abundance information to managers because travel time for salmon from the mouth of the river to the sonar site is 2 to 3 days (Figure 1). The Andreafsky River is the only major salmon spawning tributary downstream of the sonar site (Figure 2); therefore, the majority of migrating salmon in the Yukon River pass the sonar project on their way to the spawning grounds.

The Alaska Department of Fish and Game's (ADF&G) primary role is to manage for sustained yield under Article VIII of the Alaska Constitution, but Alaska is also obligated to manage Yukon River salmon stocks according to precautionary, abundance-based harvest-sharing principals set forth in the Yukon River Salmon Agreement (Yukon River Panel 2004). The goal of bi-national, coordinated management of Chinook and chum salmon stocks is to meet escapement requirements that will ensure sufficient fish availability for sustained harvests in both the United States and Canada in the future. Furthermore, managers follow guidelines specified by state regulations through management plans for Yukon River Chinook, summer chum, fall chum, and coho salmon. Accurate daily salmon abundance estimates help managers regulate fishing inseason to meet harvest and escapement objectives, and are also used postseason to determine whether treaty obligations were met and to judge effects of management actions.

Prior to 1993, ADF&G used dual-beam sonar equipment that operated at 420 kHz. For the 1993 season, ADF&G changed the existing sonar equipment to operate at a frequency of 120 kHz to allow greater ensonification range by reducing signal loss, and helped increase fish detection at longer ranges (Fleischman et al. 1995). The newly configured equipment's performance was verified using standard acoustic targets in the field.

Until 1995, ADF&G attempted to identify direction of travel of detected targets by aiming transducers at an upstream or downstream oblique angle relative to fish travel. This technique was discontinued in 1995 in favor of aiming transducers perpendicular to fish travel to maximize fish detection (Maxwell et al. 1997). Because of this change and subsequent changes in counting procedures, data collected from 1995 to 2015 are not directly comparable to previous years. In 2001, the equipment was changed from dual-beam to the current split-beam sonar system configured to operate at 120 kHz (Pfisterer 2002). Reference to the use of dual-beam sonar at the Pilot Station sonar project can be found in *Yukon River project report, 2000* (Rich 2001). The split-beam technology has the ability to estimate the 3-dimensional position of a target in space which allows the testing of assumptions about direction of travel and vertical distribution of fish moving through the acoustic beam (Burwen et al. 1995).

A series of gillnets using different mesh sizes are drifted through the acoustic sampling areas to apportion the passage estimates to species. In 2004, the selectivity model used in species apportionment was refined through biometric review and analysis of historical catch data from the project's test fishery. The model providing the best overall fit to the data was a Pearson model with a tangle parameter (Bromaghin 2004). Species proportions and passage estimates reported in this document were generated using this apportionment model, and are comparable to estimates from 1995 to 2004, because estimates from these years have been regenerated using the most current model.

Early in the 2005 season, the Yukon River experienced high water levels and erosion, causing the formation of a cut bank and steepening the bottom profile on the left bank. The altered bottom profile allowed fish to swim under the beam, and increased nearshore fish distribution on the left bank. On June 19, 2005, a multi-beam dual-frequency identification sonar (DIDSON[1]) (Belcher et al. 2002) was deployed in this area to verify nearshore fish detection. The wider beam angle, video-like images, and software algorithms that can remove bottom structure from the image allowed the DIDSON system to detect fish passage within 20 m despite high water levels and problematic erosion, and it was operated for the remainder of the season, supplanting split-beam counts in this section of nearshore region. From 2005 until 2014, the project has used a combination of fixed-location split-beam and DIDSON, operating side-by-side, to estimate daily upstream passage of fish. The DIDSON sampled the first 20 m of the left bank nearshore stratum and the remainder of the range was sampled by the split-beam. Beginning in 2015 the DIDSON was replaced with an adaptive resolution imaging sonar (ARIS). The ARIS, when equipped with the telephoto lens, is capable of ensonifying the first 50 m of the left bank.

[1] Product names used in this report are included for scientific completeness but do not constitute a product endorsement.

During the 2008 season, ADF&G implemented a feasibility study to validate a complete switch over from paper charts to electronic echograms for counting fish traces (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). The electronic charts were found to provide a number of advantages that include increased number of threshold levels, better consistency (no ribbons that fade), less downtime related to paper jams, and the ability to easily determine direction of travel. In 2009, electronic echograms replaced paper charts for counting fish traces (Lozori and McIntosh 2013).

Many sonar projects operate 24 hours per day, including the Sheenjek River and Eagle sonars (Dunbar 2013; Crane and Dunbar 2011), as did the Pilot Station sonar project occasionally during developmental years in 1984 and 1985 (Mesiar et al. 1986). Funding reductions during the 1986 season necessitated staffing reductions, and a systematic sampling schedule of three 3-hour sonar periods per day was adopted (Mesiar and LaFlamme 1991). The presence of diel migration patterns would have invalidated this type of sample design; however, sonar feasibility studies in the lower Kuskokwim and Yukon Rivers during 1980–1983 found no evidence of such patterns. Variance estimates for total fish passage were first developed by Brannian (1986) and for passage by species by Fleischman et al. (1992). Parametric and non-parametric confidence intervals were developed in 1993 (Fleischman et al. 1995).

OBJECTIVES

The primary goal of this project is to estimate daily fish passage, by species, during upstream migration past the sonar site.

The primary project objective was as follows:

1. Provide managers with timely estimates, and associated confidence intervals of daily and seasonal passage of adult Chinook, chum, and coho salmon.

Secondary project objectives were as follows:

1. Collect biological data from all fish captured in the test fishery, including species, sex, length, and scales, as appropriate.
2. Collect Chinook, chum, and coho salmon tissue samples for separate genetic stock identification projects.
3. Collect water temperature data representative of the ensonified areas of the river.

STUDY SITE

Locations in this report are referenced by the proximate bank of the Yukon River, relative to a downstream perspective. At the sonar site the left bank is south of the right bank. Both the village of Pilot Station and the ADF&G sonar camp are located on the right bank.

The Yukon River, at the sonar site, is approximately 1,000 m wide between the left and right bank transducers (Figure 3). The left bank substrate, composed of silt and fine sand, drops off gradually at a vertical angle of approximately 2° to 4°. The right bank has a stable, rocky bottom that drops off uniformly to the thalweg at a vertical angle of approximately 10° (Figure 4). The thalweg is approximately 25 m deep and is located approximately 200 m offshore of the right bank. River height, as observed from 2001 to 2015 at the United States Geological Survey (USGS) gaging station located downstream of the project, has ranged from a maximum of 28.9 ft to a minimum of 13.6 ft from June 1 through September 7 (Figure 5).

METHODS

Daily upstream migration of targeted fish species are estimated by multiplying the daily sonar passage of all species with the daily proportion of each targeted fish species estimated from the drift gillnet test fishery conducted in the same area as the sonar (Figure 6). Test fishing and sonar sampling were stratified both temporally and physically. The temporal stratification occurs through multiple test fishing and sonar periods per day (Table 1). The physical stratification for test fishery sampling is accomplished with different fishing zones, and for sonar sampling by dividing the right bank into 2 strata (S1 and S2), and dividing the left bank into 3 strata (S3, S4, and S5) (Figure 7).

HYDROACOUSTIC DATA ACQUISITION

Equipment

Left bank sonar equipment included the following:

1. A Hydroacoustic Technology Inc. (HTI) Model 244 echosounder configured to transmit and receive at 120 kHz, controlled via Digital Echo Processing (DEP) software installed on a laptop PC,
2. An HTI 120 kHz split-beam transducer with a 3° x 10° nominal beam width,
3. A 250 ft (76.2 m) HTI split-beam transducer cable connecting the sounder to the transducer,
4. An ARIS Explorer 1200 unit equipped with a telephoto lens, configured to transmit and receive at 0.7 MHz, and controlled via software installed on a laptop PC, and
5. A 150 m ARIS underwater cable connecting the ARIS to the “topside breakout box” and laptop PC.

Right bank sonar equipment included:

1. An HTI Model 244 echosounder configured to operate at 120 kHz, controlled via DEP software installed on a laptop PC,
2. An HTI split-beam 120 kHz transducer with a 6° x 10° nominal beam width, and
3. Three 250 ft (228.6 m combined length) HTI split-beam cables connecting the sounder to the transducer.

The HTI Model 244 echosounders are ideal for use at the project due to their configurability and power. The echosounders are set to transmit and receive at 120 kHz, which is necessary to achieve the sampling ranges. The beam heights for each split-beam transducer were chosen to fit the water column between the bottom and surface with minimal interference and the 10° width provides adequate field of view. The lengths of cable are necessary for flexibility in placement of the transducers. Each HTI system configuration of sounder, transducer, and cable was calibrated by the manufacturer prior to the field season. Transducers were mounted on metal tripods and remotely aimed with HTI model 662H dual-axis rotators (Figure 8), which allow for precision in aiming, especially at range with the split-beam sonar. Rotator movements were controlled with HTI model 660-2 rotator controllers with position feedback to the nearest 0.1°. The ARIS is ideal for use in the left bank nearshore stratum because it is much more robust to bottom and surface interference, and the telephoto lens is necessary to achieve the sampling range. Gasoline generators (3000 W) supplied 120 VAC power.

After echogram files were recorded, Echotastic software was used to mark fish traces. Echograms and associated data were stored on a portable hard drive and transferred to an external redundant array of independent disks (RAID) storage system.

Equipment Settings and Thresholds

The split-beam echosounders used a 40 log$R$ time-varied gain (TVG) and 0.4 ms transmit pulse duration during all sampling activities. The receiver bandwidth was automatically determined by the equipment based on the transmit pulse duration. On the left bank, the pulse repetition rate (ping rate) for S4 was set at 3 pings per second (pps) and S5 was set at 1.2 pps. The ping rate for on the right bank for S1 was set at 5 pps and S2 was set at 3 pps (Table 2). On the left bank S3 was sampled by the ARIS, which operated at an average rate of 4 frames per second with a start range of 0.69 m and an end range of 50 m, in low-frequency mode (0.7 MHz) (Table 3).

The digital sampling used by both the split-beam sonar and ARIS eliminates the use of thresholds during raw data collection. However, thresholds were applied to the electronic echogram files when viewed in Echotastic in order to reduce background noise and improve detection of fish traces (Table 4).

Aiming

Transducers were deployed on both the left and right banks in an area where the river is approximately 1,000 m wide. The transducers were always positioned and aimed to maximize fish detection. The transducer was located in the area with the best bottom profile and the beam was oriented approximately perpendicular to the current so that migrating fish would present the largest possible reflective surface. Because many fish travel close to the substrate, the maximum response angle of the beam was oriented slightly above the river bottom through as much of the range as possible. The right bank transducer was positioned as close to shore as possible depending on water level, adjusting the aim between S1 (0–40 m) and the S2 (40–150 m). The left bank split-beam transducer was positioned as close to shore as possible (depending on water level), and utilized 2 distinct aims to sample S4 (50–150 m), and S5 (150–300 m). The ARIS unit was normally deployed within 2 m of the split-beam transducer and ensonified S3 (0–50 m) (Figure 7). The ARIS's wider beam angle is ideal for the less linear nature of the eroded left bank nearshore stratum, enabling it to detect fish targets throughout more of the water column than the narrower split-beam. Additional aiming and sonar site selection protocols for fish counting with side-looking sonar systems can be found in Faulkner and Maxwell (2009).

Fluctuating water levels required repositioning of the transducers and subsequent re-aiming of the beams. To establish an optimal aim, the transducer was panned horizontally upstream and downstream approximately 15° off perpendicular in 2° increments. At each increment, the vertical tilt was adjusted to obtain the best possible bottom picture using an electronic echogram to confirm that the sonar beam was oriented slightly above the river bottom. The left bank transducers were re-aimed more often to compensate for the dynamic bottom conditions and continual changes associated with that bank. Once an optimal aim was obtained, the rotator settings were documented and the auto rotator settings changed for the new optimal aim.

Sampling Procedures

Acoustic sampling was conducted simultaneously on both banks during 3 hour periods 3 times each day (Table 1). Sample periods were scheduled from 0530–0830, 1330–1630, and 2130–0030 hours, alternating sequentially between strata every 30 minutes.

Operators marked fish traces for both the split-beam and the ARIS system on electronic echograms using Echotastic software developed by ADF&G (Figure 9; Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). All personnel were trained to distinguish between fish tracings and nontarget echoes. Echo traces were counted as a single fish if at least 2 pings in the cluster passed the threshold level (see Equipment Settings and Thresholds) and the targets did not resemble inert downstream objects. Valid downstream fish targets were marked along with upstream when computing the total estimate of fish passage for consistency with historical methods. Individuals within groups of fish were distinguishable when the apparent direction of movement of 1 fish trace differed from that of an adjacent trace.

Echograms were reviewed daily by either the project leader or crew leader to monitor the accuracy of the marked fish tracings and reduce individual biases. Each echogram was checked for indications of signal loss and changes in bottom reverberation markings, which could indicate either movement of the transducer or a change in bottom profile. The data was checked daily for data entry or marking errors, then processed in statistical software (SAS) using routines developed by Toshihide Hamazaki (ADF&G Commercial Fisheries Biometrician, Anchorage).

SYSTEM ANALYSES

Performance of the split-beam hydroacoustic system was monitored following many of the procedures first established in 1995 (Maxwell et al. 1997). Monitoring of the ARIS included daily checks of sonar settings prior to each sampling period, routine checks of water level near the pod, checking aim settings, and periodic cleaning of the transducer lens. System analyses included equipment performance checks, bottom profiles using down-looking sonar, and hydrologic measurements.

Bottom Profiles

Bottom profiles were recorded along both banks using a Lowrance LCX15MT recording fathometer with GPS capabilities to locate deployment sites with suitable linear bottom profiles. All bottom profiles were recorded and stored electronically. Inseason, the fathometer was used regularly to monitor changing bottom conditions and to watch for the formation of sandbars capable of re-routing fish to unensonified areas.

Hydrological Measurements

Water levels were sourced from the real-time USGS gaging station located approximately 500 m downstream of Pilot Station and used inseason. Electronic temperature data loggers were deployed to record water temperature on both banks on May 30. Both loggers remained submerged until August 31. The electronic temperature data loggers were programed to record the water temperature once every hour at the top of the hour. Daily temperature was calculated as the mean of all recorded temperatures for the day.

SPECIES APPORTIONMENT

To estimate species composition of the sonar estimates, gillnets were drifted through 3 zones (right bank, left bank nearshore, and left bank offshore) corresponding to sonar sampling strata (Figure 7). The results of the right bank drift (test fishing Zone 1) were applied to the 2 right bank sonar strata (S1 and S2). The results of the left bank nearshore drift (test fishing Zone 2) were applied only to the sonar estimates in the first stratum on the left bank (S3). The left bank offshore drift (test fishing Zone 3) were applied to the remainder of the left bank sonar estimates (S4 and S5).

A total of 8 different mesh sizes were fished throughout the season to effectively capture all size classes of fish present and detectable by the hydroacoustic equipment (Table 5). All nets were 25 fathoms (45.7 m) long and approximately 8 m deep. All nets were constructed of shade 11, double knot multifilament nylon twine and hung "even" at a 2:1 ratio of web to corkline.

Test fishing began as soon as practical and continued through the last day of sonar operation. Test fishing was conducted twice daily between sonar periods, from 0900–1200 hours and 1700–2000 hours, except on days when commercial gillnet fishing was scheduled (Table 1). On days of commercial gillnet fishing, only 1 test fishing period was conducted during a time to not interfere or overlap with the scheduled commercial period or a sonar operation period. During each normal sampling period, 4 different mesh sizes were drifted within each of 3 zones for a total of 24 drifts per day, except when only 1 test fishing period was conducted in which all 6 mesh sizes were fished (Table 6). The order of drifts were 1) left bank nearshore zone, 2) right bank zone, and 3) left bank offshore zone, with a minimum of 20 minutes between drifts in the same zone. Each mesh size was fished in all 3 zones before switching to the next mesh size. The shoreward end of the left bank nearshore drift was held approximately 5–10 m from the sonar transducers. The left bank offshore drift was approximately 65 m offshore of the transducers so as not to overlap with the nearshore drift. Drifts were approximately 8 minutes in duration but were shortened as necessary to avoid snags or to limit catches during times of high fish passage.

Captured fish were identified to species and length measured to the nearest 1 mm. Salmon species were measured from mid eye to fork of tail (METF); non-salmon species were measured from tip of snout to fork of tail (FL). Non-salmon species captured and identified included cisco (*Coregonus* spp.), humpback whitefish (*C. pidschian*), broad whitefish (*C. nasus*), sheefish (*Stenodus leucichthys*), burbot (*Lota lota*), longnose sucker (*Catostomus catostomus*), Dolly Varden (*Salvelinus malma*), and northern pike (*Esox lucius*). Sex was recorded only for salmon species, and was determined by examination of external features. For Chinook salmon that were retained, sex was determined by internal examination of reproductive organs. Fish species, length, and sex were recorded onto field data sheets. Each drift record included the date, sampling period, zone, drift start and end times, mesh size, length of net, and captain's initials. Handling mortalities among the captured fish were distributed to the local community and fish dispersal was documented daily.

A minimum of 3 scale samples were collected from each Chinook salmon and mounted on scale cards, and fish and card numbers were recorded on the test fishing data sheets. Data were transferred from data sheets into a Microsoft Access database. Age, sex, and length (ASL) data are processed, analyzed, and reported annually by ADF&G staff based in Anchorage (e.g., Eaton 2014).

Individual genetic tissue samples from Chinook, chum, and coho salmon were also collected, and placed in vials, for several stock identification projects, in conjunction with the test fishing portion of the project. ASL data were cross-referenced with each individual tissue sample. The ADF&G Gene Conservation Laboratory (e.g., DeCovich and Howard 2011) and the U.S. Fish and Wildlife Service (USFWS) Conservation Genetics Laboratory (e.g., Flannery and Wenburg 2015) independently processed and analyzed these tissue samples.

Chinook salmon were classified as either large (>655 mm METF) or small (≤655 mm METF), and small Chinook salmon served as a proxy for jacks. Although there is some temporal overlap between the summer and fall runs of chum salmon, for the purposes of estimating passage, all chum salmon encountered through July 18 were designated as summer chum salmon and after July 18 were designated as fall chum salmon.

ANALYTICAL METHODS

Daily estimates were produced from a multi-component process involving the following:

1. Hydroacoustic estimates of all fish targets passing the site, and species composition derived from test fishing results applied to the undifferentiated hydroacoustic estimates.
2. CPUE estimates, used as a separate index by the managers and were calculated on a subset of the test fishing data.

Sparse and Missing Data

When sufficient gillnet samples were not available for a given day and zone, the data were pooled with data from 1 or more adjacent days by assigning the same report unit (u). Sufficient gillnet samples were not available during commercial gillnet fishing periods, because test fishing was not conducted during these times, and during times of low fish passage when catches were too sparse to accurately estimate species proportions and associated error bounds.

CPUE estimates were calculated on a daily basis irrespective of catch size. In contrast, species passage estimates were first calculated on the basis of report units (encompassing 1 or more full days of sampling within a zone), and then apportioned into daily estimates. For any test fishing variable (x) the report unit (u) encompasses day (d), test fishing period (p), and zone (z) such that:

$$x_u = \sum_{d,p,z}^{u} x_{dpz} \; . \tag{1}$$

The report unit was also appended to the corresponding days and zones of sonar passage estimates. In effect, any unique combination of day and zone having sufficient test fishing catch was assigned a unique report unit (u), and combinations that did not have sufficient catch for accurate apportionment were initially pooled by assigning the same report unit across adjacent days within the same zone. When pooling resulted in sufficient test fishing catch, estimates by species could then be calculated, and those species estimates were in turn re-apportioned back into daily estimates on the basis of sonar passage estimates during that time-frame.

Catch Per Unit Effort

CPUE estimates used as separate indexes by the managers, and not for species apportionment, were calculated for each day (d) and bank (b) using 2 gillnet suites (g) of specific size mesh (m). Chinook salmon CPUE was calculated on the pooled catch (c) and effort (f) of the large mesh gillnets (7.5 in and 8.5 in); chum and coho salmon CPUE was calculated on the pooled catch and effort of the small mesh gillnets (5.25 in, 5.75 in, and 6.5 in).

The duration of the test fishing drift (j) in minutes (t) was calculated as:

$$t_j = (SI_j - FO_j) + \frac{(FO_j - SO_j)}{2} + \frac{(FI_j - SI_j)}{2}, \tag{2}$$

where:

- SO = the time the net is initially set out,
- FO = the time the net is fully set out,
- SI = the time the net starts back in, and
- FI = the time the net is fully retrieved in.

The total fishing effort (in fathom-hours) for each day, bank, and gillnet suite was calculated as:

$$f_{dbg} = \sum_g \frac{25 \cdot t_{dbg}}{60}, \tag{3}$$

because all nets were 25 fathoms (45.7 m) in length. CPUE estimates (in catch per fathom-hour) for each species (i) were made daily for the right and left banks as:

$$CPUE_{dbi} = \frac{\sum_g c_{dbig}}{f_{dbg}}. \tag{4}$$

Species Composition

To estimate species proportions, first the total effort (f) in fathom-hours of drift (j) with mesh size (m) during report unit (u) was calculated by multiplying the drift time (t) (Equation 3) for each mesh, drift, and reporting unit by 25 fathoms and dividing by 60 minutes per hour as:

$$f_{umj} = \frac{25 \cdot t_{umj}}{60}. \tag{5}$$

Total effort for each mesh size fished was then summed over each report unit:

$$f_{um} = \sum_j f_{umj}, \tag{6}$$

and the catch of species (i) of length (l) in each report unit (u) was summed across all mesh sizes:

$$c_{uil} = \sum_m c_{uilm}. \tag{7}$$

For the catch of each species (i) of length (l), the associated effort was adjusted by applying a length-based selectivity parameter (S) (Appendix A1) derived from the Pearson T net selectivity model (Bromaghin 2004) as:

$$f'_{uil} = \sum_m (S_{ilm} \cdot f_{um}), \tag{8}$$

and the CPUE of the catch of each species (i) of length (l) was calculated as:

$$CPUE'_{uil} = \frac{c_{uil}}{f'_{uil}}. \tag{9}$$

The proportion (p) of species (i) during report unit (u) was estimated as the ratio of the CPUE for species (i) to the CPUE of all species combined:

$$\hat{p}_{ui} = \frac{\sum_{l} CPUE'_{uil}}{\sum_{i,l} CPUE'_{uil}}, \tag{10}$$

and the variance was estimated from the squared differences between the proportion for each test fishing period (x) for each day (d) within the report unit ($\hat{p}_{udxi}$) and the proportion for the report unit as a whole ($\hat{p}_{ui}$):

$$\hat{V}ar(\hat{p}_{ui}) = \frac{\sum \left(\hat{p}_{ui} - \hat{p}_{udxi}\right)^2}{n_u \cdot \left(n_u - 1\right)}, \tag{11}$$

where n_u is the number of test fishing sampling periods within the report unit.

Sonar Passage Estimates

Total fish passage was estimated separately for each of the same 3 test fishery zones used in the species apportionment. Test fishing Zone 1 consisted of the entire counting range on the right bank, corresponding to S1 and S2 (approximately 0–150 m). Test fishing Zone 2 consisted of the counting range corresponding to S3 (approximately 0–50 m on the left bank). Test fishing Zone 3 consisted of the counting range corresponding to S4 and S5 (approximately 50–150 m and 150–300 m on the left bank, respectively) (Figure 7).

Total upstream fish passage (y) on day (d), during sonar period (p), in zone (z), and stratum (s) was calculated by summing net upstream targets over all sectors (k) and samples (q):

$$y_{dpzs} = \sum_{q} \sum_{k} y_{dpzsqk}, \tag{12}$$

and the duration, in hours (h), of the time sampled as:

$$h_{dpzs} = \sum_{q} \sum_{k} h_{dpzsqk}. \tag{13}$$

The hourly passage rate (r) for day (d), sonar period (p), and zone (z) was computed as a ratio of the sum of the estimated upstream passage in stratum (s) to the duration (hours) of the sample:

$$r_{dpz} = \frac{\sum_{s} y_{dpzs}}{\sum_{s} h_{dpzs}}. \tag{14}$$

Total passage of fish in a report unit ($\hat{y}_u$) was estimated as the product of the average hourly passage rate and the total hours encompassed by the report unit:

$$\hat{y}_u = \left(d_2 - d_1 + 1\right)_u \cdot 24 \cdot \left(\frac{\sum_{d,p,z \in u} r_{dpz}}{n_u} \right), \tag{15}$$

where d_1 is the first day, d_2 is the last day, and n_u is the number of sonar sampling periods in report unit (u).

Sonar sampling periods, each 3 hours in duration, were spaced at regular (systematic) intervals of 8 hours. Treating the systematically sampled sonar counts as a simple random sample could yield an over-estimate of the variance of the total, because sonar counts are highly auto correlated (Wolter 1985). To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations, recommended by Brannian (1986) and modified from Wolter (1985), was employed:

$$\hat{V}ar(\hat{y}_u) = \left[\left(d_2 - d_1 + 1\right)_u \cdot 24\right]^2 \cdot \left[1 - \frac{h_u}{\left(d_2 - d_1 + 1\right)_u \cdot 24}\right] \cdot \frac{\sum_{p=2}^{n_u} (r_{up} - r_{u,p-1})^2}{2n_u(n_u - 1)}, \tag{16}$$

where r_{up} is the passage rate in reporting unit (u) for period (p), and

$$1 - \frac{h_u}{\left(d_2 - d_1 + 1\right)_u \cdot 24}, \tag{17}$$

is the finite population correction factor.

Fish Passage by Species

The passage of species (i) was estimated for each report unit (u) as the product of the species proportion (p) (Equation 10) and sonar passage (y) (Equation 15):

$$\hat{y}_{ui} = \hat{y}_u \cdot \hat{p}_{ui}. \tag{18}$$

Except for the timing of sonar and gillnet sampling periods, sonar-derived estimates of total fish passage were independent of gillnet-derived estimates of species proportions. Therefore, the variance of their product (daily species passage estimates y_{idz}) was estimated as the variance of the product of 2 independent random variables (Goodman 1960):

$$\hat{V}ar\left(\hat{y}_{ui}\right) = \hat{y}_u^2 \cdot \hat{V}ar\left(\hat{p}_{ui}\right) + \hat{p}_{ui}^2 \cdot \hat{V}ar\left(\hat{y}_u\right) - \hat{V}ar\left(\hat{y}_u\right) \cdot \hat{V}ar\left(\hat{p}_{ui}\right). \tag{19}$$

Passage estimates were assumed independent between reporting units, and therefore the variance of their sum was estimated by the sum of their variances:

$$\hat{V}ar\left(\hat{y}_i\right) = \sum_u \hat{V}ar\left(\hat{y}_{ui}\right). \tag{20}$$

Because most users of this data were interested in daily passage by species rather than passage for reporting units, the daily species passage by zone was estimated by calculating the proportion of the hourly passage rate for the day and zone to the hourly passage rate for the report unit:

$$\hat{p}_{dz} = \frac{r_{udz}}{r_u}. \tag{21}$$

and then applying the passage proportion (p) to the report unit estimate (y):

$$\hat{y}_{dzi} = \hat{y}_{ui} \cdot \hat{p}_{dz}. \tag{22}$$

Total daily passage by species was estimated by summing over all zones:

$$\hat{y}_{di} = \sum_{z} \hat{y}_{dzi}. \tag{23}$$

At this stage, there were 2 potential ways of calculating total season passage summing the estimates across days or reporting units. Each can produce slightly different totals due to small rounding errors. To prevent confusion, passage estimates were summed over all zones and days to obtain a seasonal estimate for species (y_i) because this is how the estimates are reported:

$$\hat{y}_i = \sum_{d} \sum_{z} \hat{y}_{dzi}. \tag{24}$$

Assuming normally distributed errors, 90% confidence intervals were calculated as:

$$\hat{y}_i \pm 1.645\sqrt{\hat{V}ar(\hat{y}_i)}. \tag{25}$$

Using SAS program code (Toshihide Hamazaki, Commercial Fisheries Biometrician, ADF&G, Anchorage; personal communication), CPUE, passage estimates, and estimates of variance were calculated.

RESULTS

The Pilot Station sonar project crew arrived at the sonar site on May 25 and began camp setup. Test fishing began on the evening of May 28. The right bank split-beam sonar was deployed and operational for Period 2 sonar on May 30. The left bank split-beam sonar was deployed on May 30 and was operational for Period 2 sonar on May 31. The ARIS was deployed on May 30 and was operational for Period 2 sonar on May 31. The project was fully operational beginning with Period 2 sonar on May 31 and continued operations through August 31. Passage estimates were transmitted to fishery managers in Emmonak daily.

ENVIRONMENTAL AND HYDROLOGICAL CONDITIONS

Ice breakup on the Yukon River at Pilot Station occurred on May 14, which is 2 days earlier than average and allowed camp to be set up early (Table 7). The water level during the 2015 season was above the 2001–2014 mean during the first 2 weeks of June near Pilot Station, but dropped during mid-June and remained below the 2001–2014 mean until September 2, when it again rose above the mean (Figure 5). Mean daily water temperatures on the left bank ranged from 11.9–19.0°C and 11.6–20.17°C on the right bank (Figure 10).

TEST FISHING

Drift gillnetting resulted in the capture of 8,106 fish; 450 Chinook salmon, 2,806 summer chum salmon, 2,137 fall chum salmon, 695 coho salmon, and 2,018 fish of other species. Of the captured fish, 1,870 (23.1%) were retained as mortalities and delivered to local users to help meet subsistence needs within the nearby community of Pilot Station (Table 8). Of the 450 Chinook salmon captured in the test fishery, scale samples were collected from 450. Tissue samples for genetic stock identification were collected from 444 Chinook salmon, 4,924 chum salmon, and 694 coho salmon. Daily CPUE data are reported in Appendices B1 and B2.

HYDROACOUSTIC ESTIMATES

An estimated 3,422,703 fish passed through the sonar sampling areas between May 31 and August 31. Of that total passage, 1,041,464 (30.4%) fish passed along the right bank, 1,117,500 (32.6%) fish passed along the left bank nearshore, and 1,263,739 (36.9%) fish passed along the left bank offshore (Table 9). Total fish passage estimates, by zone and with their associated errors, were calculated daily (Appendix C1).

On the left bank, over 90% of the fish passage occurred within 110 m of the transducer in the summer season. During the fall season, distribution was slightly more dispersed because approximately 90% of the fish passage occurred within 140 m. On the right bank, approximately 90% of the fish passage occurred within 80 m during both summer and fall seasons (Figures 11–12).

SPECIES ESTIMATES

Fish passage estimates by species were generated daily and then reported to fishery managers (Appendix D1). The cumulative passage estimates for Chinook salmon, with 90% confidence intervals, was 86,620 ± 23,678 large Chinook salmon (>655 mm METF) and 29,464 ± 18,465 small Chinook salmon (≤655 mm METF). The cumulative passage estimates for chum salmon was 1,385,083 ± 103,203 summer chum salmon and 546,894 ± 44,039 fall chum salmon. The cumulative passage estimate for coho salmon was 97,587 ± 15,280 fish, for pink salmon was 22,421 ± 11,817 fish, and for other species (whitefish, cisco, sheefish, burbot, longnose sucker, Dolly Varden, sockeye salmon, and northern pike) was 1,254,634 ± 90,067 fish (Table 9).

The initial pulse of Chinook salmon began on June 13 and summer chum salmon began 3 days later on June 16 (Figure 13). Compared to historical mean run timing for 2004–2014, the midpoint of the Chinook salmon run occurred 2 days early (June 24) and was on time (June 28) for summer chum salmon (Figure 14; Appendices E1 and E2).

There were 6 pulses of fall chum salmon observed after July 18 and the first pulse occurred approximately July 20 (Figure 15). Inseason mixed stock analysis (MSA) from the Pilot Station sonar project test fishery was used to generate stock composition estimates of pulses, which were distributed inseason to assist in management decisions. Of the 5 pulses of fall chum salmon, the summer chum salmon composition ranged from 64.0% to 3.5% and the fall chum salmon composition ranged from 36.0% to 96.5% (Table 10). The midpoint of the fall chum salmon run fell on August 13, which was 3 days late when compared to 2004–2014 mean cumulative run timing (Figure 16; Appendices E1 and E2).

The first pulse of coho salmon arrived approximately August 14. There were several additional pulses of coho salmon through August 31 (Figure 15). As in most years, the project ends before the coho salmon run is complete and estimates are considered conservative. Small numbers of coho salmon continued to enter the Yukon River after August 31 and were monitored at the Lower Yukon test fishery (LYTF) near Emmonak through September 20 (Estensen et al. 2015). The midpoint of the coho salmon run was on August 22, which was 1 day late when compared to 2004–2014 mean cumulative run timing (Figure 16; Appendices E1 and E2).

MISSING DATA

During initial startup, between May 30 and May 31, at least 1 bank had partial days of sonar operation. The right bank split-beam sonar began operating during Period 2 on May 30. The left bank split-beam sonar and ARIS began operating during Period 2 on May 31. Also, at the beginning of the summer season, there were 9 days (May 28–June 5) that had insufficient catch in at least 1 zone.

The first commercial gillnetting period occurred on July 8 in District 2, and that canceled 1 test fishing period for that day. Commercial fishing continued through the remainder of the summer season, and 5 additional commercial gillnet fishing periods in District 2 that canceled 1 of the daily test fishing periods on each of those days. During the fall season, 12 commercial fishing periods occurred in District 2 that canceled 1 of the daily test fishing periods on each of those days. During the month of August, there were 6 days (August 6–7, 10–11, and 17–18) that had insufficient catch in at least 1 zone. In order to estimate variance accurately, days with missing test fishing periods were pooled with adjacent days that had 2 complete test fishing periods, and zones with insufficient catches were pooled with zones with sufficient catches on adjacent days (Table 11).

DISCUSSION

The right bank bottom profiles were similar to prior years with little or no change throughout the season. The left bank profiles remained linear throughout the season, and there were no problems in finding suitable transducer locations. Whereas in previous years there have been problems with silt attenuation or reverberation bands, in 2015 there were no serious problems with either. Bathymetric surveys of the sonar site this season indicated progression of the mid-river sandbar upstream of the left bank sampling area. Until 2009, when it regressed, the mid-river sandbar had been a normal river feature (Lozori and McIntosh 2013). A concern in recent years has been the left bank sandbar downstream of the ensonified area. During periods of low water, this sandbar, which is located in the left bank nearshore test fishing zone, can cause nets to drag the bottom and stall. It is uncertain if the sandbar forces the fish further offshore and causes them to remain farther offshore after they have made their way around the sandbar, but during the 2009 field season, it was speculated that fall chum salmon estimates may have been underestimated because of effects caused by the sandbar (Lozori and McIntosh 2013). The left bank sandbar did seem to affect fish distribution this season and fish appeared to move offshore slightly when compared to previous years.

Chinook salmon passage estimates at the Pilot Station sonar project for 2015 were below the 2014 estimates, and were the 14th highest since 1995. Summer chum salmon passage estimates for 2015 were below the 2014 estimates, and ranked 11th, which is slightly below the 50th percentile. Fall chum salmon passage estimates at the Pilot Station sonar project for 2015 were below the 2014 estimates, and ranked 12th, which is below the 50th percentile. The total estimated coho salmon passage at the Pilot Station sonar project was below the 2014 estimates, and the third lowest passage on record since 1995 (Appendix F1).

Although there were very few problems this season, estimating fish passage on the Yukon River continues to present major technical and logistical challenges. The sampling environment is often demanding due to the extremely dynamic nature of the water level, turbidity, bottom substrate, and range-dependent signal loss. The hydroacoustic system employed at the Pilot Station sonar project appears to work well for the purpose of detecting migrating salmon, but successful estimation depends on constant attention to the frequent changes and diligent re-checking of every part of the acoustic and environmental system. In 2015, all project goals were met and passage estimates were given to fisheries managers daily during the season. Information generated at the Pilot Station sonar project was also disseminated weekly through multi-agency international teleconferences and data sharing with stakeholders in areas from the Lower Yukon River, all the way to the spawning grounds in Canada.

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TABLES AND FIGURES

Table 1.–Daily sampling schedule for sonar and test fishing, at the Pilot Station sonar project on the Yukon River, 2015.

	Sonar		
Time	Right bank	Left bank	Test fishing
	Period 1		
0530	S1	S3/S4	
0600	S2	S5	
0630	S1	S3/S4	
0700	S2	S5	
0730	S1	S3/S4	
0800	S2	S5	
0830			
0900			Period 1
0930			
1000			
1030			
1100			
1130			
1200			
1230			
1300	Period 2		
1330	S1	S3/S4	
1400	S2	S5	
1430	S1	S3/S4	
1500	S2	S5	
1530	S1	S3/S4	
1600	S2	S5	
1630			
1700			Period 2
1730			
1800			
1830			
1900			
1930			
2000			
2030			
2100	Period 3		
2130	S1	S3/S4	
2200	S2	S5	
2230	S1	S3/S4	
2300	S2	S5	
2330	S1	S3/S4	
0000	S2	S5	

Table 2.–Initial split-beam sonar settings, at the Pilot Station sonar project on the Yukon River, 2015.

			Bank	
Component	Setting	Stratum	Left	Right
Transducer	Beam size (h x w)		3º x 10º	6º x 10º
Echosounder	Transmit power (dB)	S1		30.0
		S2		30.0
		S4	30.0	
		S5	30.0	
	Receiver gain (dB)	S1		-14.0
		S2		-14.0
		S4	-12.0	
		S5	-12.0	
	Source level (dBµPa @ 1m)	S1		221.2
		S2		221.2
		S4	223.1	
		S5	223.1	
	Through-system gain (dB)		-161.5	-162.5
	Pulse width (ms)		0.4	0.4
	Blanking range (m)		2.0	2.0
	Ping rate (pps)	S1		5.0
		S2		3.0
		S4	3.0	
		S5	1.2	
	Range (m)	S1		40
		S2		150
		S4	150	
		S5	300	

Table 3.–Technical specifications for the adaptive resolution imaging sonar (ARIS), at the Pilot Station sonar project on the Yukon River, 2015.

Setting	Value
Field of view (h x w)	14° x 28°
Detection frequency (MHz)	0.7
Receiver gain (dB)	20.0
Samples/beam	1,706.0
Start range (m)	0.69
Frame rate (f/s)	4.0
Range (m)	50.0

Table 4.–Range of lower and upper thresholds used in Echotastic, at the Pilot Station sonar project on the Yukon River, 2015.

		Threshold (dB)	
Bank	Stratum	Upper	Lower
Right	S1	-17	-80
	S2	-15	-70
Left	S3	0	-75
	S4	-5	-70
	S5	0	-58

Table 5.–Specifications for drift gillnets used for test fishing, by season, at the Pilot Station sonar project on the Yukon River, 2015.

	Stretch mesh size		Mesh diameter	Meshes deep	Depth
Season	(in)	(mm)	(mm)	(MD)	(m)
Summer	2.75	70	44	131	8.0
(5/28–7/18)	4.00	102	65	90	8.0
	5.25	133	85	69	8.0
	6.50	165	105	55	7.9
	7.50	191	121	48	8.0
	8.50	216	137	43	8.1
Fall	2.75	70	44	131	8.0
(7/19–8/31)	4.00	102	65	90	8.0
	5.00	127	81	72	8.0
	5.75	146	93	63	8.0
	6.50	165	105	55	7.9
	7.50	191	121	48	8.0

Table 6.–Fishing schedule for drift gillnets used for test fishing by season, at the Pilot Station sonar project on the Yukon River, 2015.

	Test fishing	Mesh size (in)			
Season	period	Odd days		Even days	
Summer	1	2.75	5.25	8.50	4.00
(5/28–7/18)		7.50	6.50	7.50	6.50
	2	7.50	6.50	7.50	6.50
		8.50	4.00	2.75	5.25
Fall	1	4.00	5.75	2.75	7.50
(7/19–8/31)		5.00	6.50	5.00	6.50
	2	5.00	6.50	5.00	6.50
		2.75	7.50	4.00	5.75

Table 7.–Yukon River ice breakup dates at Pilot Station, 2001–2015.

Year	Breakup Date
2015	5/14
2014	5/03
2013	5/31
2012	5/17
2011	5/17
2010	5/19
2009	5/17
2008	5/19
2007	5/11
2006	5/25
2005	5/11
2004	5/03
2003	5/15
2002	5/18
2001	5/29

Source: National Oceanic and Atmospheric Administration (NOAA). 2015. National Weather Service, Alaska-Pacific River Forecast Center. aprfc.arh.gov/php/brkup/breakupDb.php (Accessed: October 2015).

Table 8.–Number of fish caught and retained in the Pilot Station sonar project test fishery on the Yukon River, 2015.

Total catch	Chinook	S. Chum	F. Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others [a]	Total
May	3	2	0	0	0	0	7	8	1	36	1	58
June	359	1,860	0	0	0	0	73	118	20	157	37	2,624
July	86	944	809	39	18	45	366	328	9	31	37	2,712
August	2	0	1,328	11	677	39	213	356	25	9	52	2,712
Total	450	2,806	2,137	50	695	84	659	810	55	233	127	8,106

Fish retained	Chinook	S. Chum	F. Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others [a]	Total
May	1	2	0	0	0	0	0	0	0	11	0	14
June	30	682	0	0	0	0	10	5	0	61	0	788
July	5	181	208	22	7	0	59	0	2	6	1	491
August	0	0	399	3	135	0	35	1	2	1	1	577
Total	36	865	607	25	142	0	104	6	4	79	2	1,870

Proportion retained	Chinook	S. Chum	F. Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others [a]	Total
May	0.333	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.306	0.000	0.241
June	0.084	0.367	0.000	0.000	0.000	0.000	0.137	0.042	0.000	0.389	0.000	0.300
July	0.057	0.192	0.257	0.564	0.389	0.000	0.161	0.000	0.222	0.194	0.027	0.181
August	0.000	0.000	0.300	0.273	0.199	0.000	0.164	0.003	0.080	0.111	0.019	0.213
Total	0.080	0.308	0.284	0.500	0.204	0.000	0.158	0.007	0.073	0.339	0.016	0.231

[a] Includes longnose sucker, northern pike and Dolly Varden.

Table 9.–Cumulative fish passage estimates by zone and species with standard errors (SE) and 90% confidence intervals (CI), at the Pilot Station sonar project on the Yukon River, 2015.

		Left bank				90% CI	
Species	Right bank	Nearshore	Offshore	Total passage	SE	Lower	Upper
Large Chinook [a]	10,061	26,039	50,520	86,620	14,394	62,942	110,298
Small Chinook [b]	5,184	8,006	16,274	29,464	11,225	10,999	47,929
Total Chinook	15,245	34,045	66,794	116,084	18,253	86,058	146,110
Summer chum	364,821	372,662	647,600	1,385,083	62,738	1,281,880	1,488,286
Fall chum	145,682	107,222	293,990	546,894	26,772	502,855	590,933
Coho	50,089	13,673	33,825	97,587	9,289	82,307	112,867
Pink	2,756	16,594	3,071	22,421	7,184	10,604	34,238
Other	462,871	573,304	218,459	1,254,634	54,752	1,164,567	1,344,701
Total	1,041,464	1,117,500	1,263,739	3,422,703			

[a] Large Chinook >655 mm.

[b] Small Chinook ≤655 mm.

Table 10.–Genetic composition of chum salmon, sampled at the Pilot Station sonar project on the Yukon River, 2015.

	Percentage	
Date	Summer chum	Fall chum
5/30–6/21	99.6	0.4
6/22–7/05	96.6	3.4
7/06–7/18	98.6	1.4
7/19–7/22	64.0	36.0
7/23–8/02	31.6	68.4
8/03–8/11	11.5	88.5
8/12–8/16	3.5	96.5
8/17–8/24	4.2	95.8
8/25–8/31	5.1	94.9

Table 11.–Reporting units of zones pooled for the 2015 season, at the Pilot Station sonar project on the Yukon River.

Date	Right Bank (Zone 1)	Left bank		Reason for pooling [a]
		Nearshore (Zone 2)	Offshore (Zone 3)	
5/28				
5/29				
5/30	1	2		
5/31			3	IC
6/1				
6/2				
6/3				
6/4				
6/5			10	IC
7/7				
7/8	106	107	108	CO
7/9				
7/10	109	110	111	CO
7/11				
7/12	112	113	114	CO
7/13				
7/14	115	116	117	CO
7/15				
7/16	118	119	120	CO
7/17				
7/18	121	122	123	CO
7/21				
7/22	130	131	132	CO
7/25				
7/26	139	140	141	CO
7/31				
8/1	154	155	156	CO
8/4				
8/5	163	164	165	CO
8/6				
8/7			168	IC

-continued-

Table 11.–Page 2 of 2.

Date	Right Bank (Zone 1)	Left Bank Nearshore (Zone 2)	Left Bank Offshore (Zone 3)	Reason for pooling [a]
8/8				
8/9	171	172		CO
8/10			173	IC
8/11				
8/12				
8/13	178	179	180	CO
8/15				
8/16	184	185	186	CO
8/17				
8/18			189	IC
8/19				
8/20	192	193	194	CO
8/23				
8/24	201	202	203	CO
8/25				
8/26	204	205	206	CO
8/27				
8/28	207	208	209	CO
8/30				
8/31	213	214	215	CO

[a] CO denotes that a commercial opening prevented test fishing, and therefore pooling across days enables the variance estimation of species proportions. IC denotes that zones were pooled when there was insufficient catch in the test fishery for variance estimation.

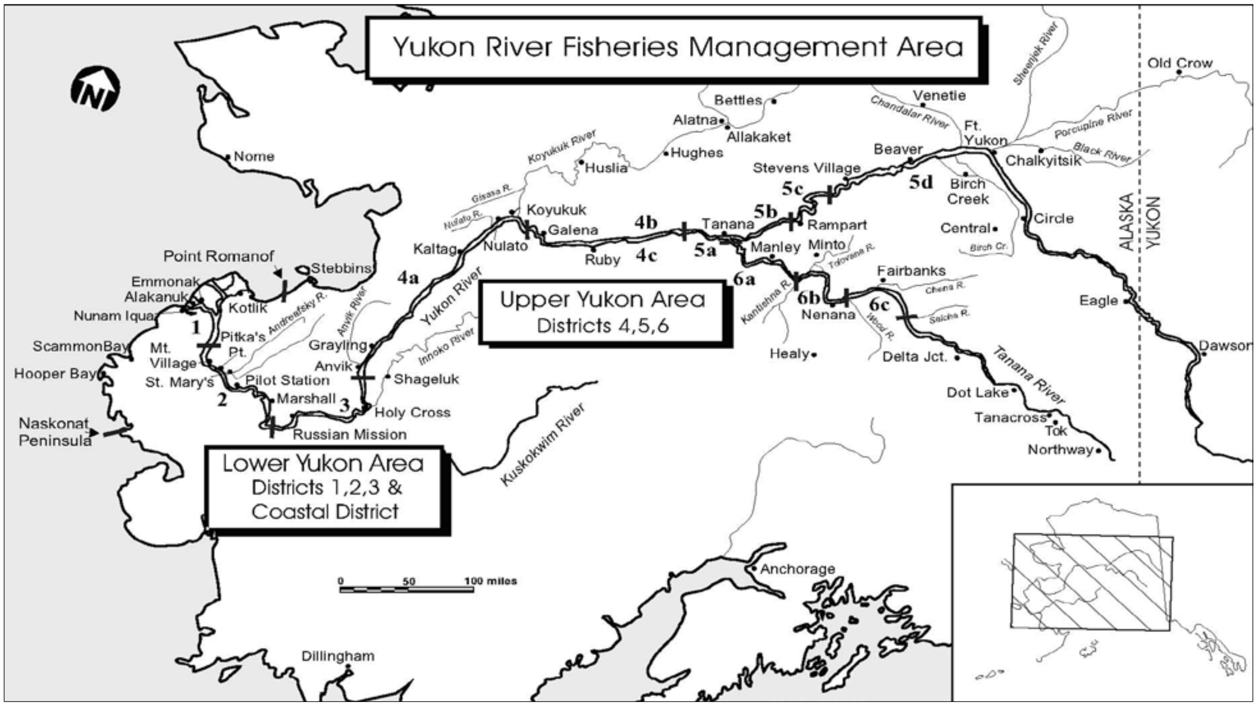


Figure 1.–Fishing districts and communities of the Yukon River drainage.

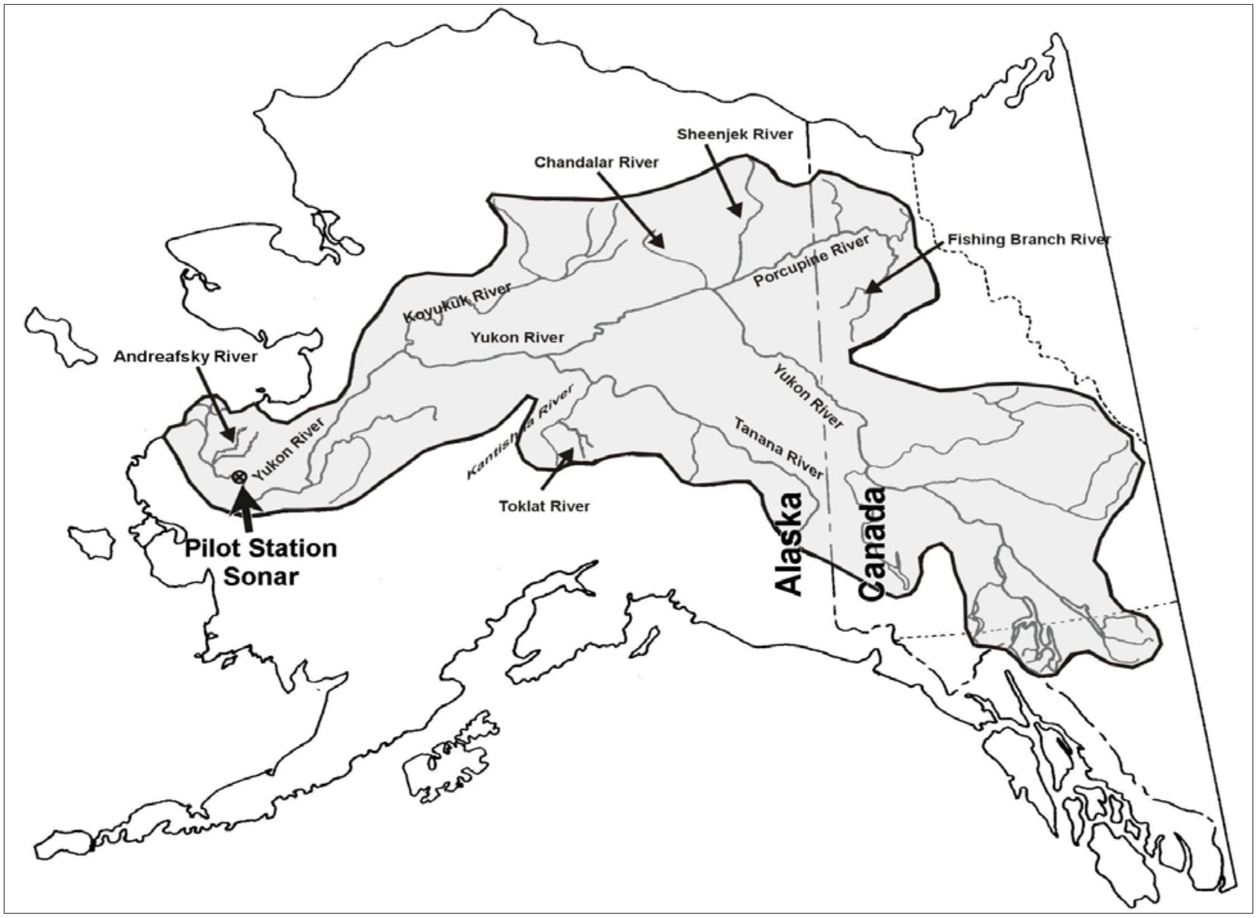


Figure 2.–Extent of the Yukon River watershed.

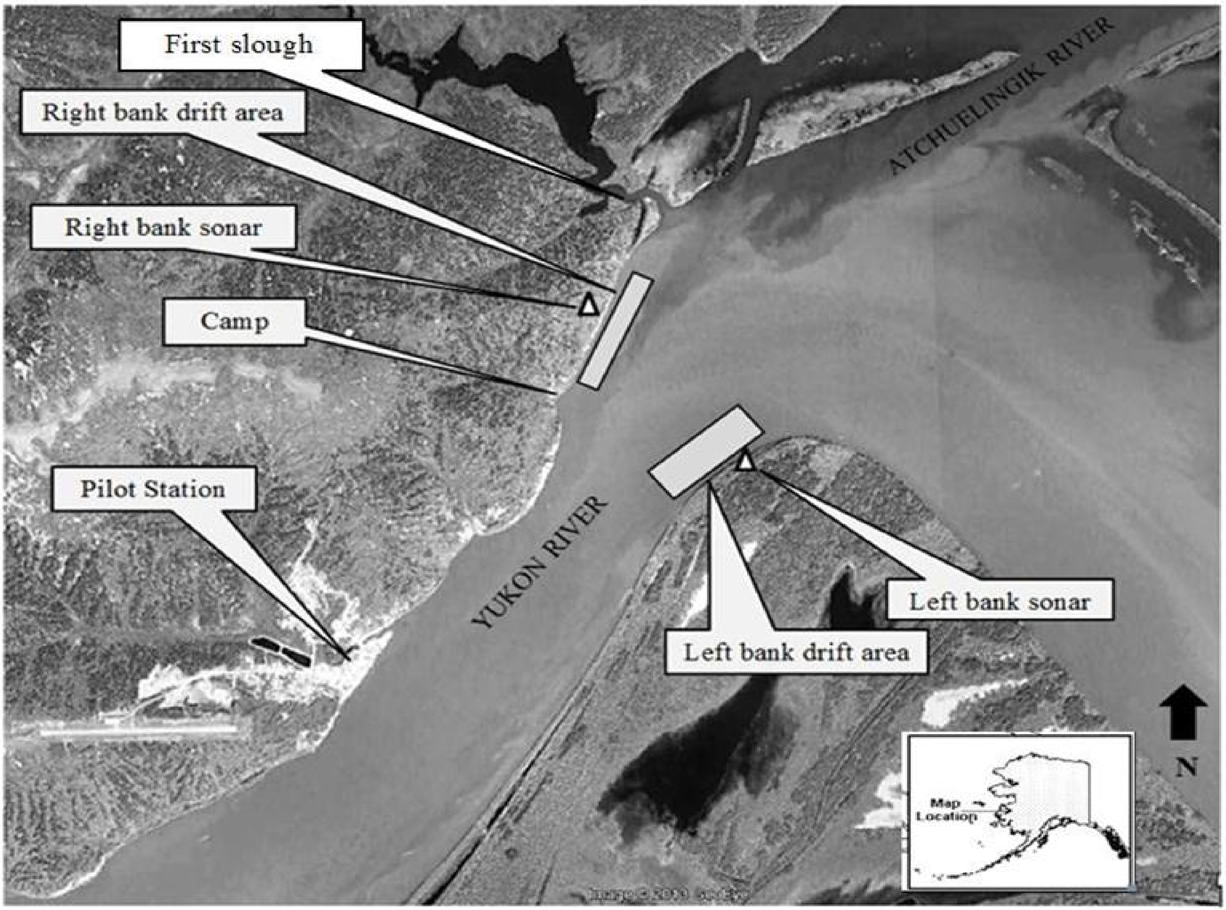


Figure 3.–Location of the Pilot Station sonar project on the Yukon River showing general transducer sites.

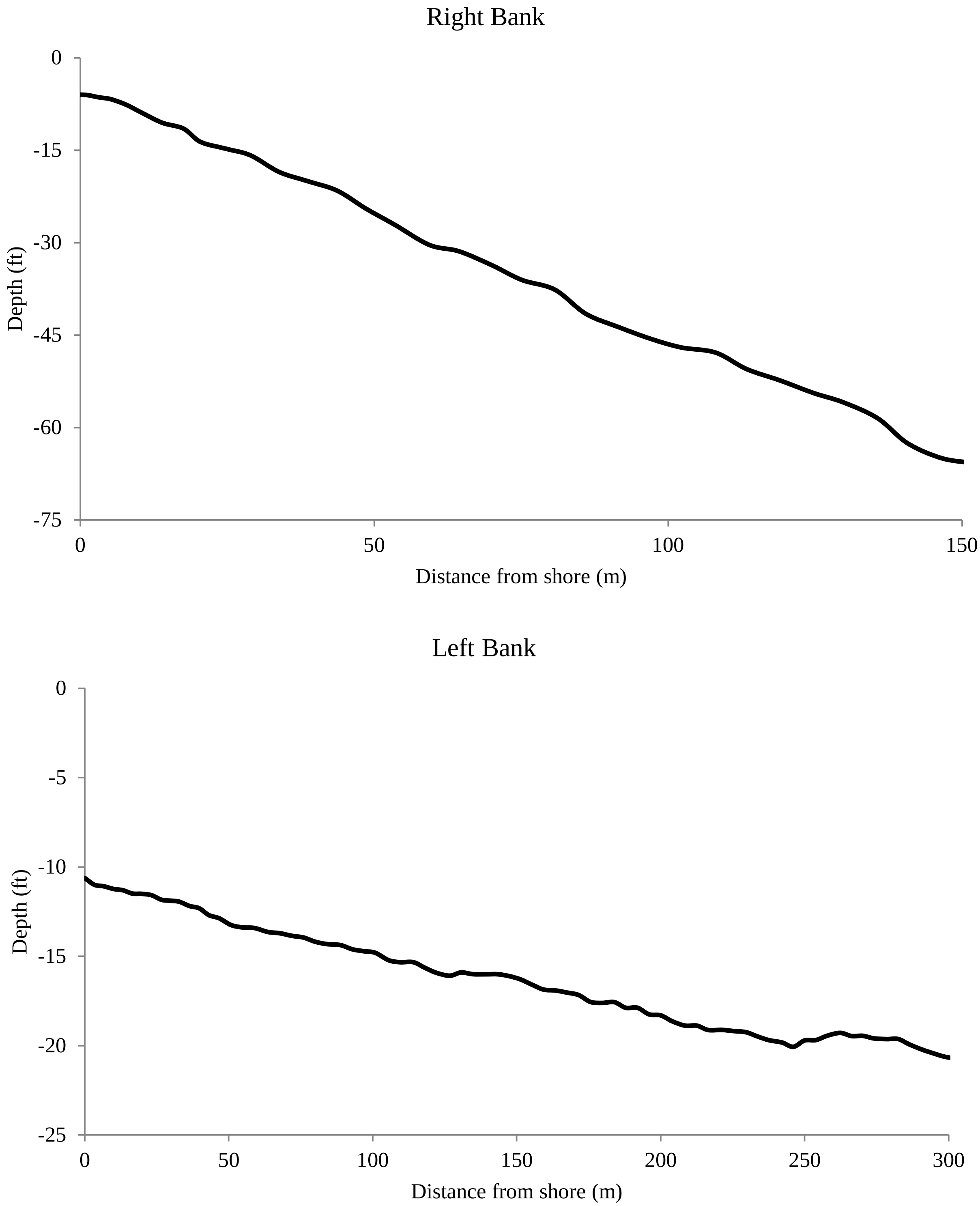


Figure 4.–Bottom profiles for the right bank (top) and left bank (bottom), at the Pilot Station sonar project on the Yukon River, 2015.

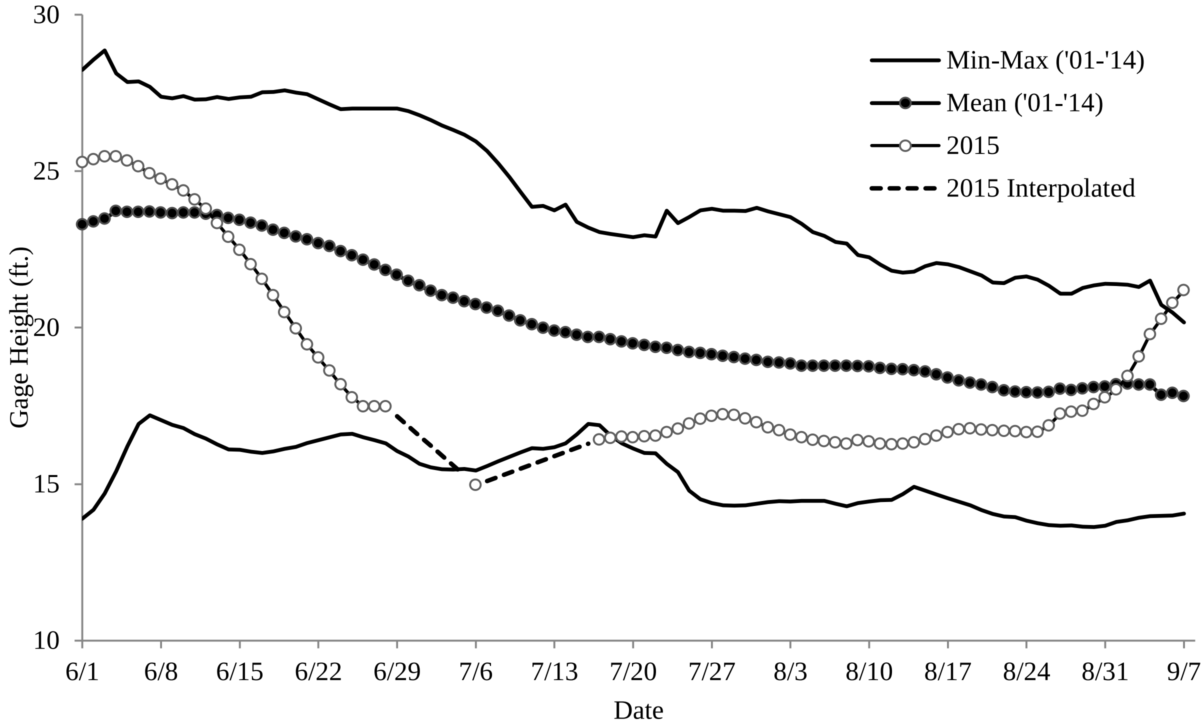


Figure 5.–Yukon River daily water level during the 2015 season at Pilot Station water gage compared to minimum, maximum, and mean gage height 2001 to 2014.

Source: United States Geological Service.

Note: Data interpolated June 29–July 16.

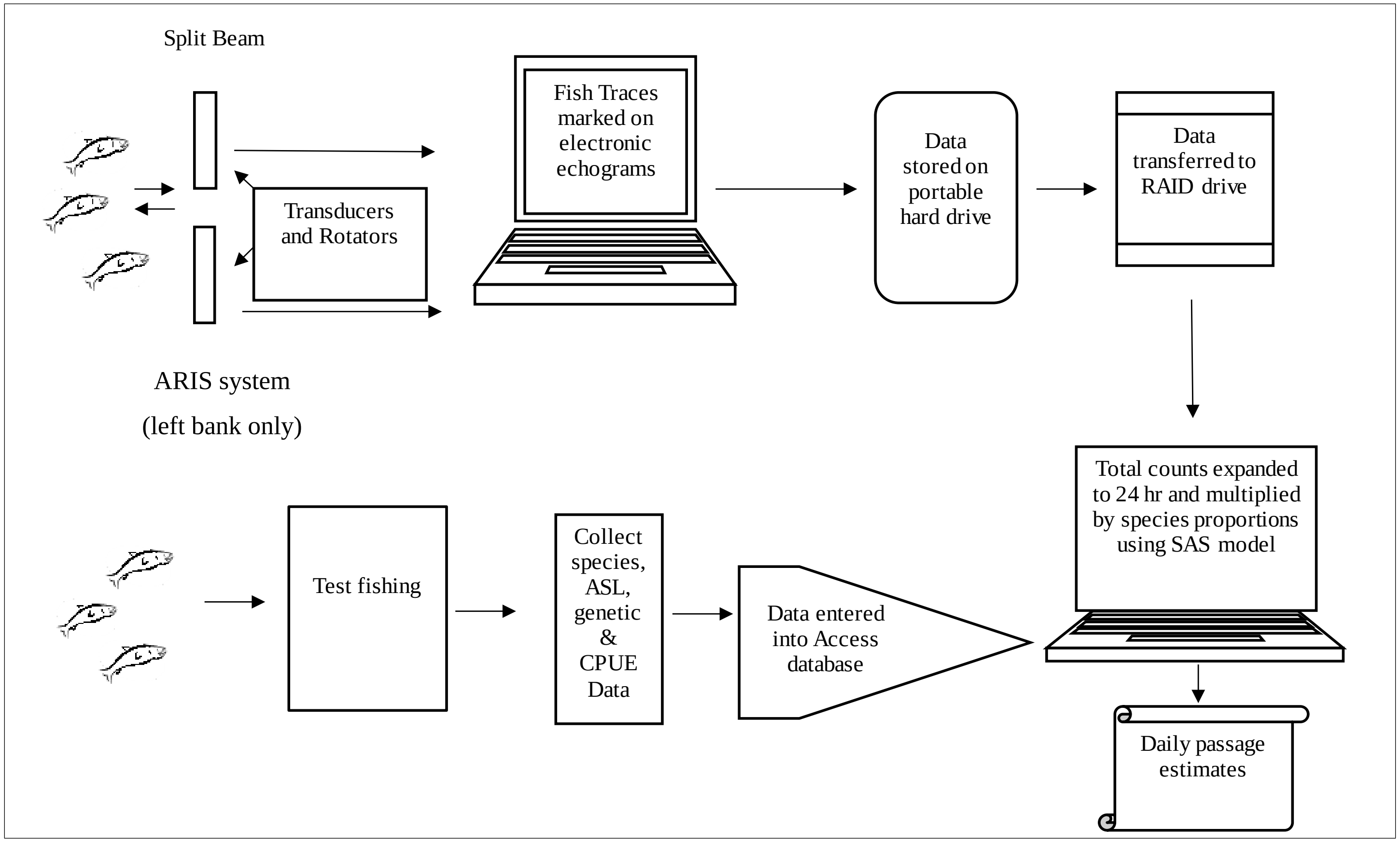


Figure 6.–Flow diagram of data collection and processing, at the Pilot Station sonar project on the Yukon River, 2015.

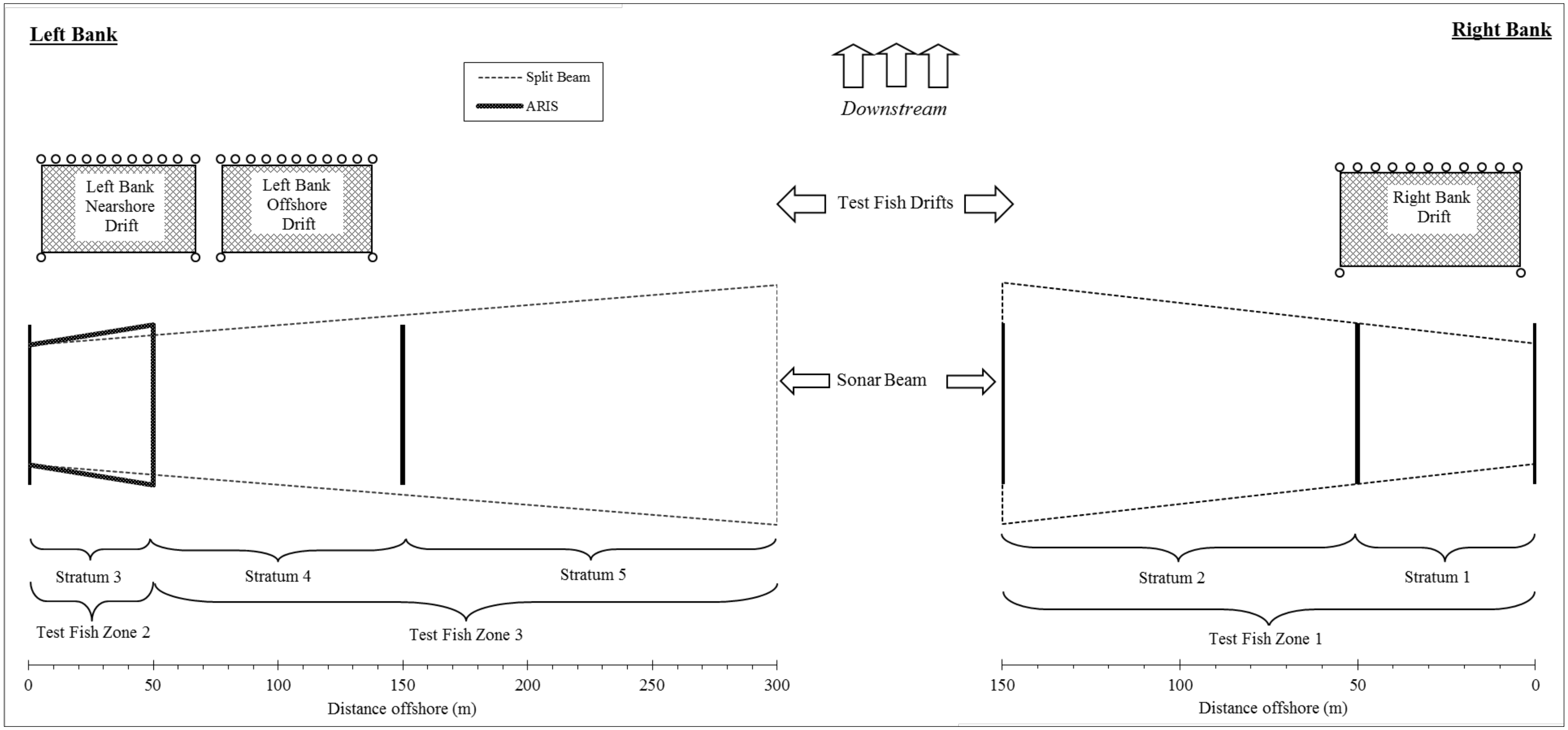


Figure 7.–Illustration of relationships between strata, test fishing zones, test fishing drifts, and approximate sonar ranges (not to scale), at the Pilot Station sonar project on the Yukon River, 2015.

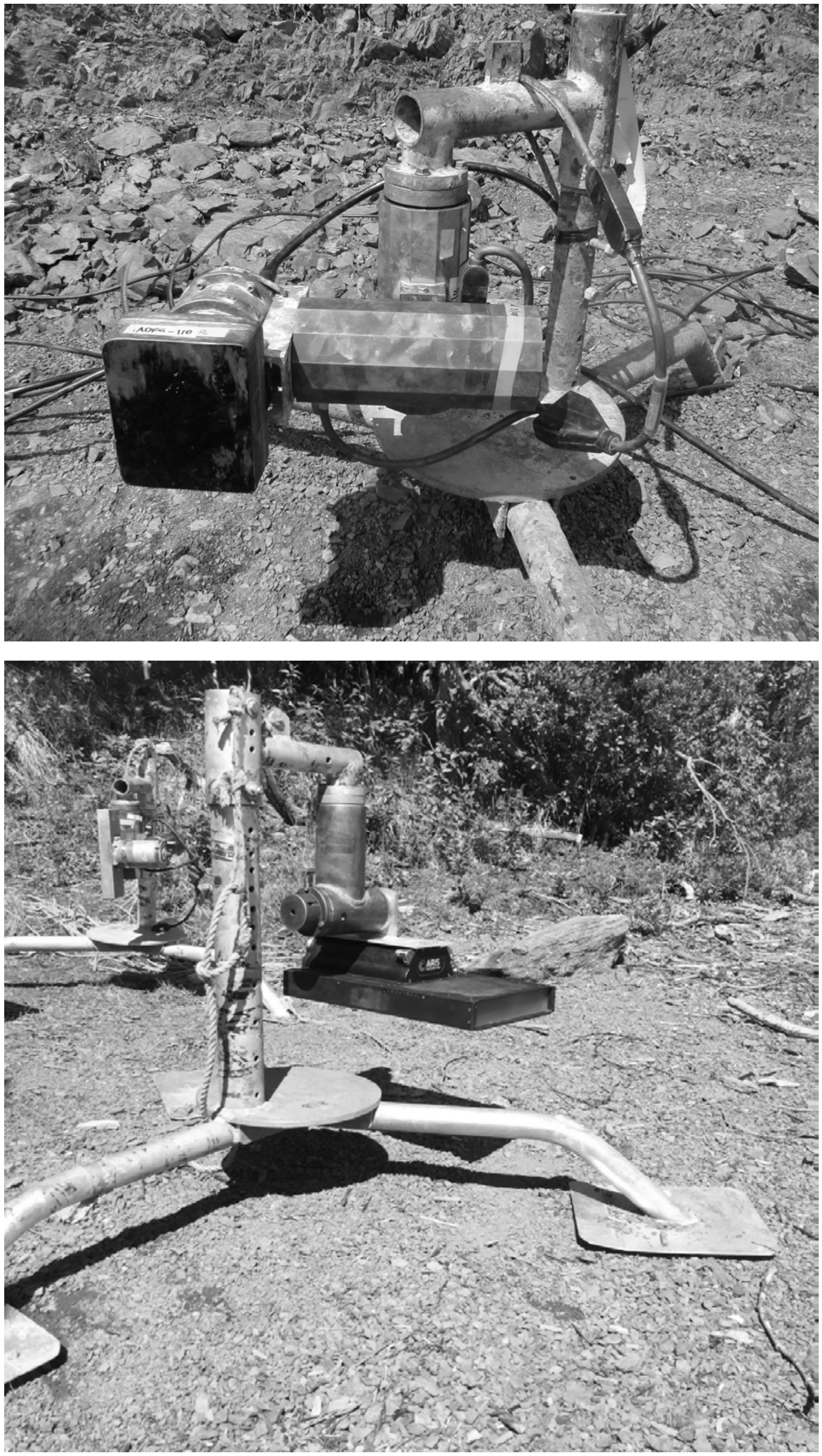


Figure 8.–Split-beam transducer mounted to pod with 662H dual axis rotators (top), and ARIS with telephoto lens mounted to pod with PT-25 rotator (bottom), at the Pilot Station sonar project on the Yukon River.

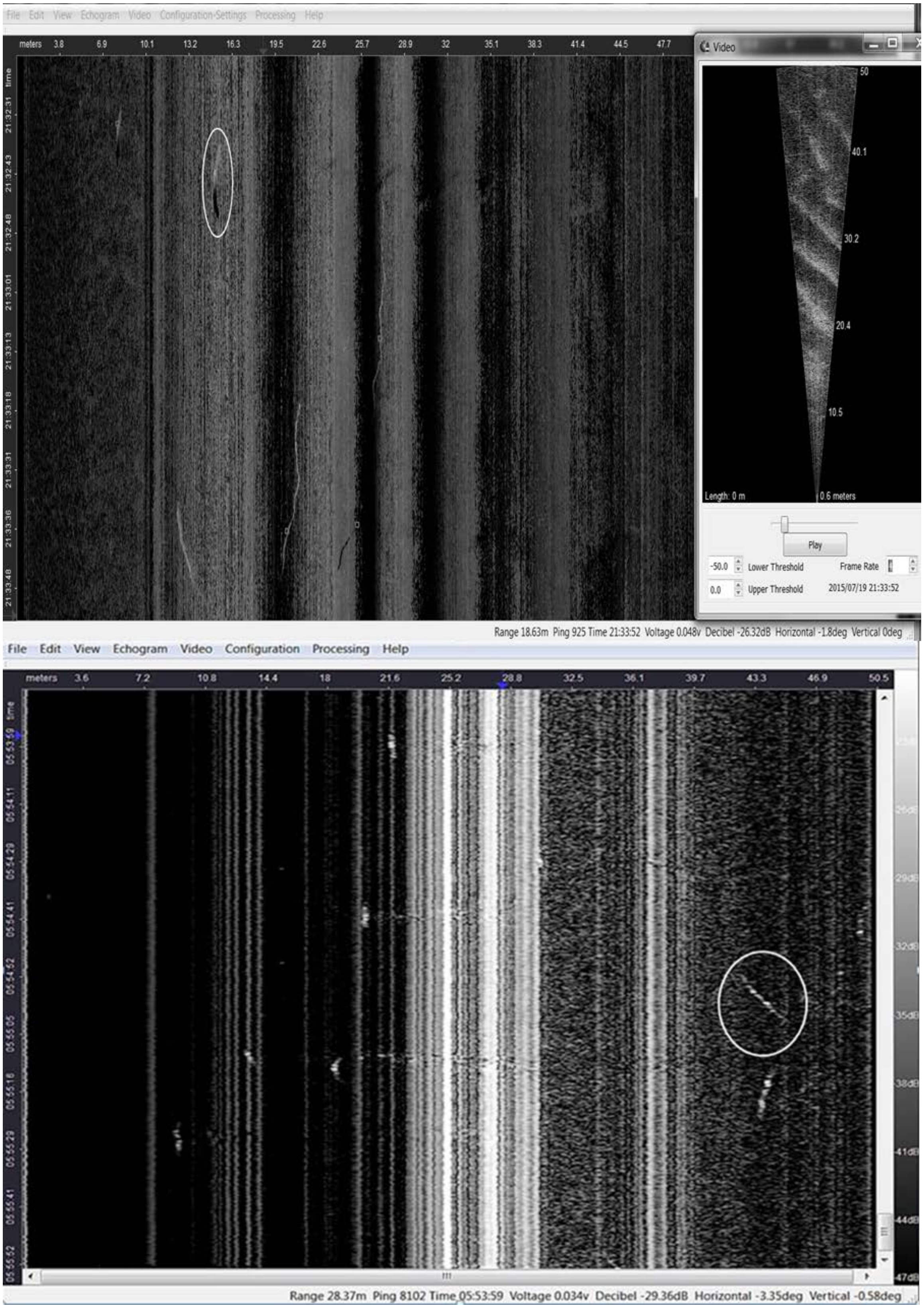


Figure 9.–Echogram of ARIS alongside video image (top) and split-beam sonar (bottom), with oval around representative fish.

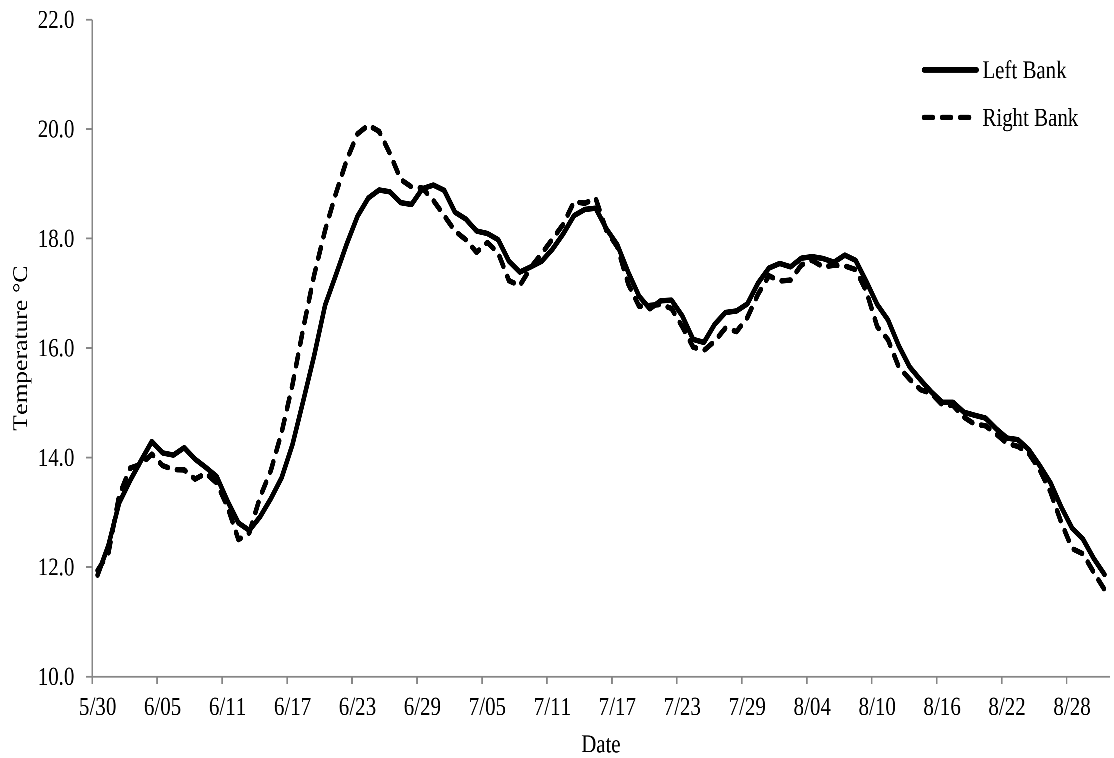
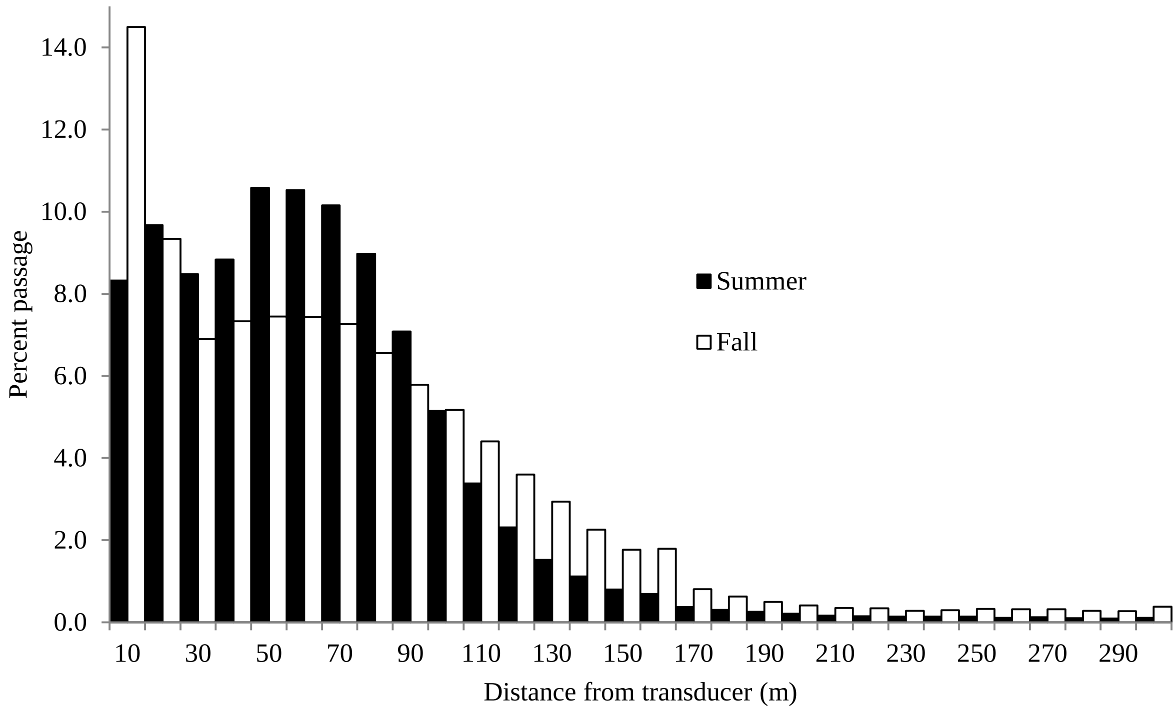


Figure 10.–Mean daily water temperatures, by bank, recorded at the Pilot Station sonar project on the Yukon River with electronic data loggers, 2015.



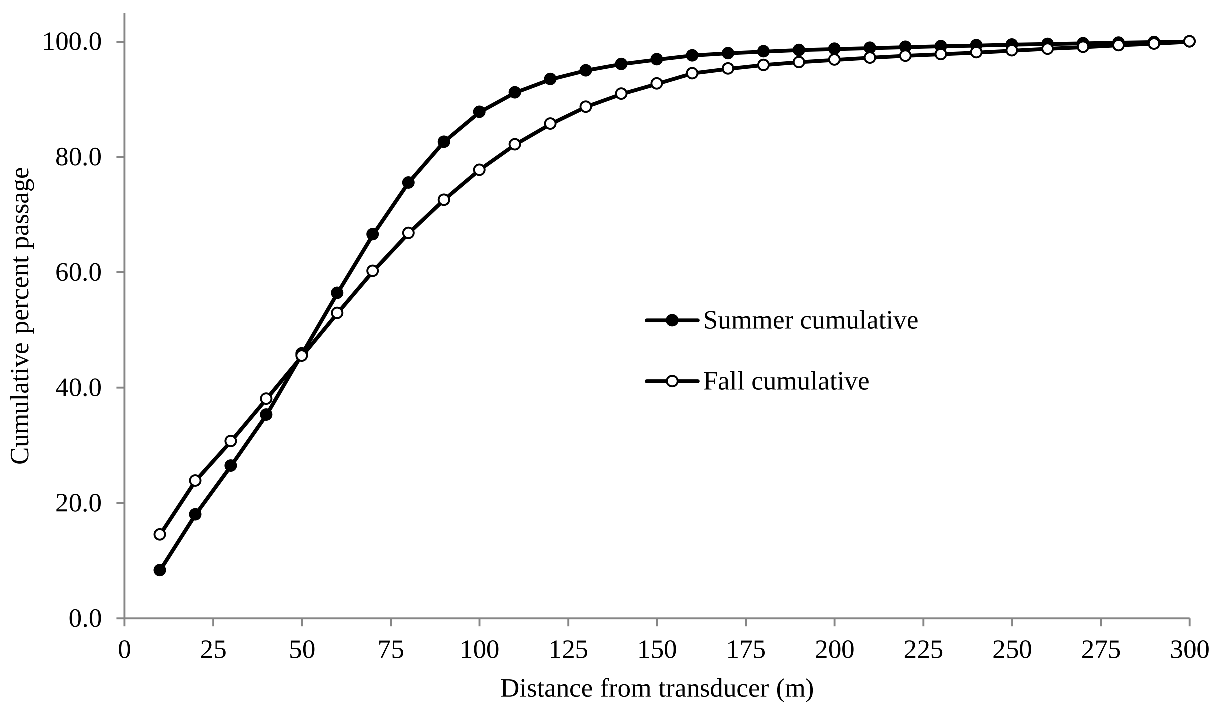
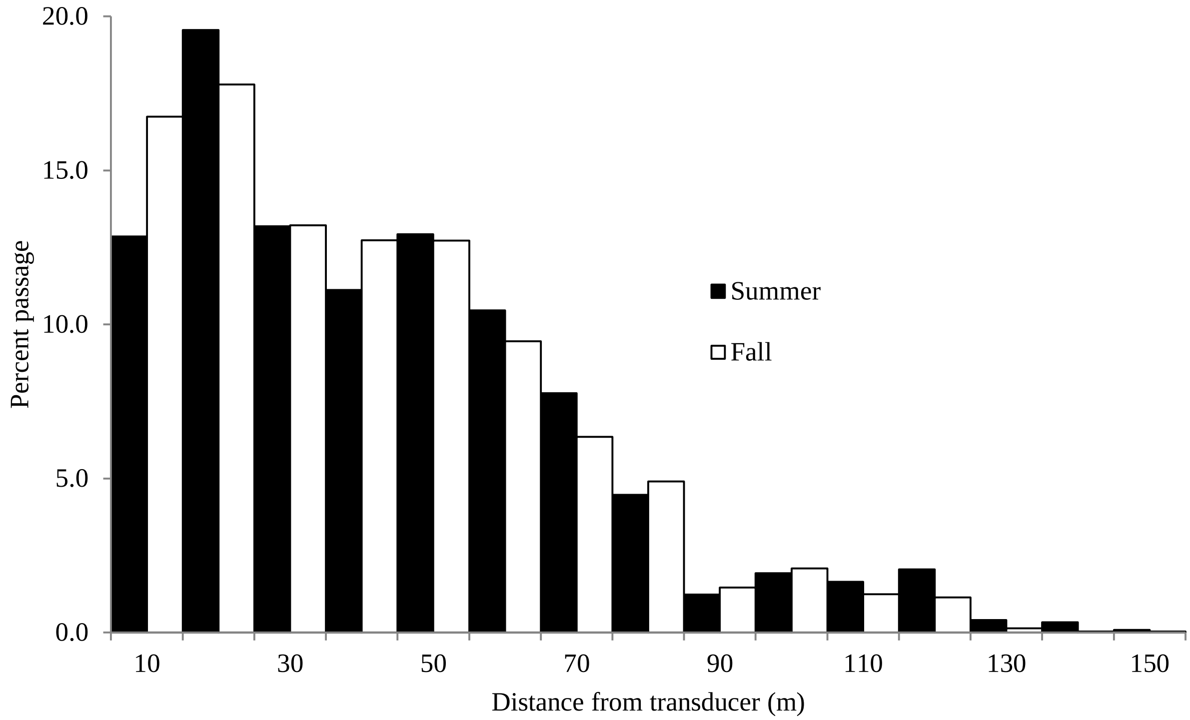


Figure 11.–Distribution of left bank passage (top) and cumulative passage as a function of range (bottom), at the Pilot Station sonar project on the Yukon River, 2015.



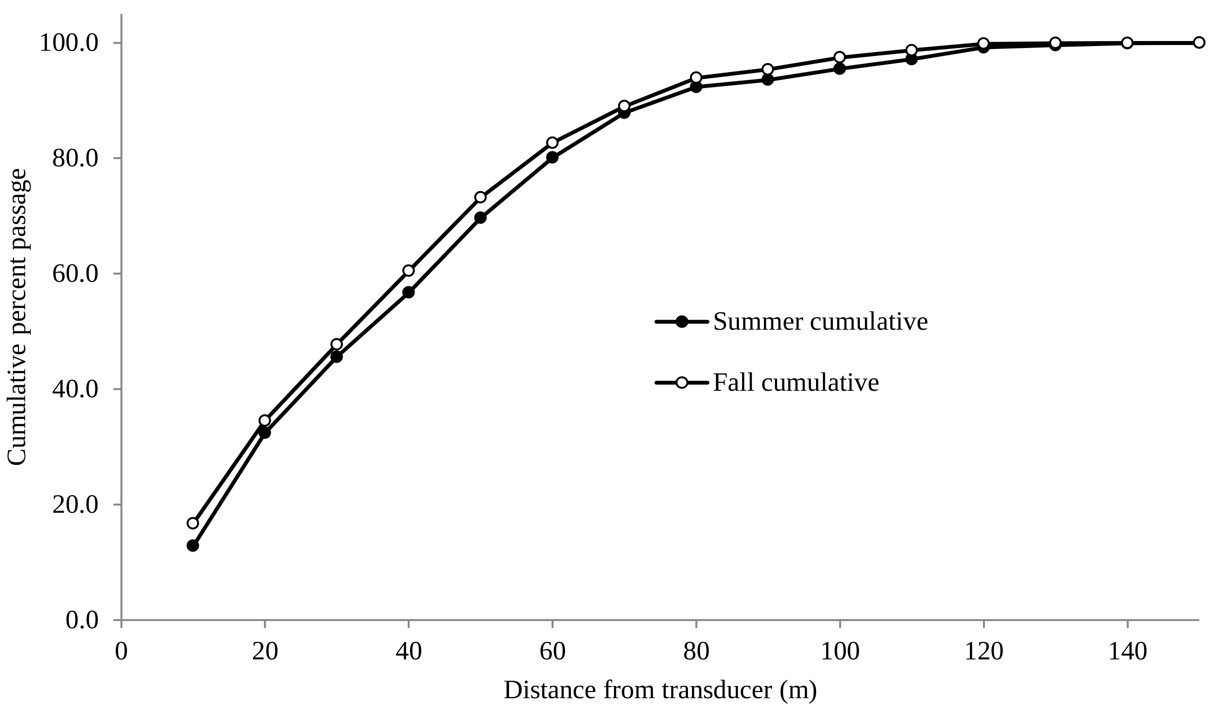
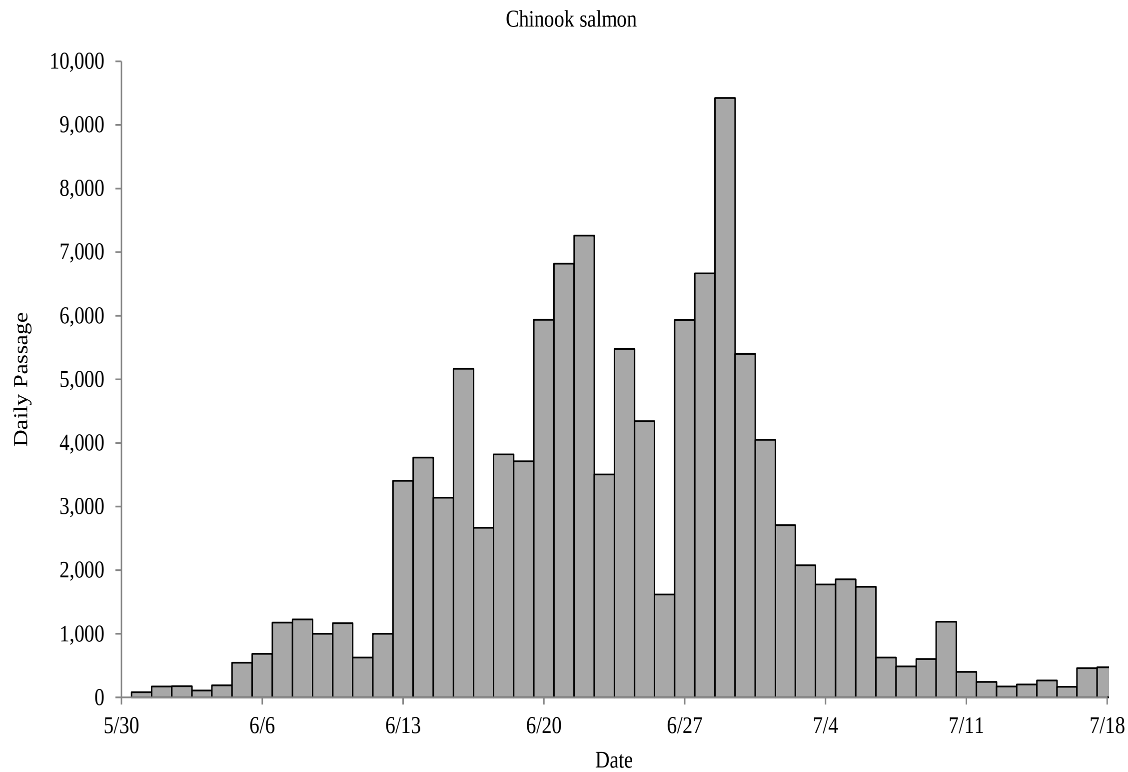


Figure 12.–Distribution of right bank passage (top) and cumulative passage as a function of range (bottom), at the Pilot Station sonar project on the Yukon River, 2015.



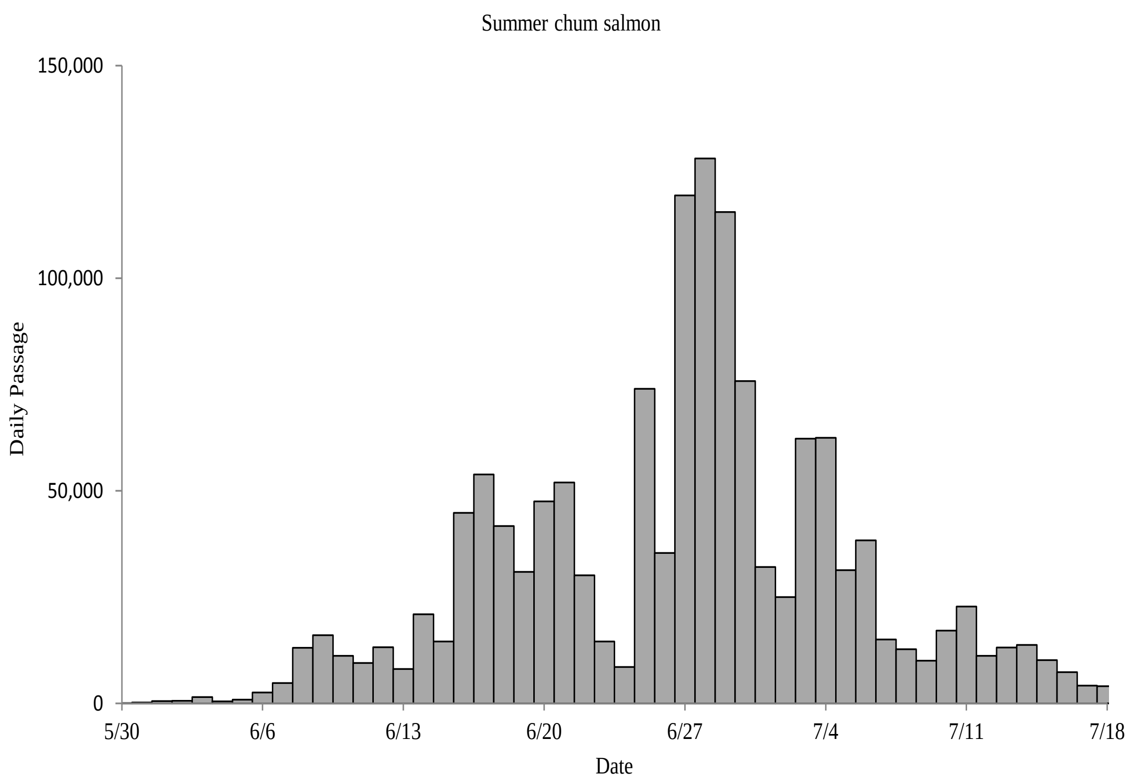


Figure 13.–Chinook and summer chum salmon daily passage estimates, at the Pilot Station sonar projects on the Yukon River, 2015.

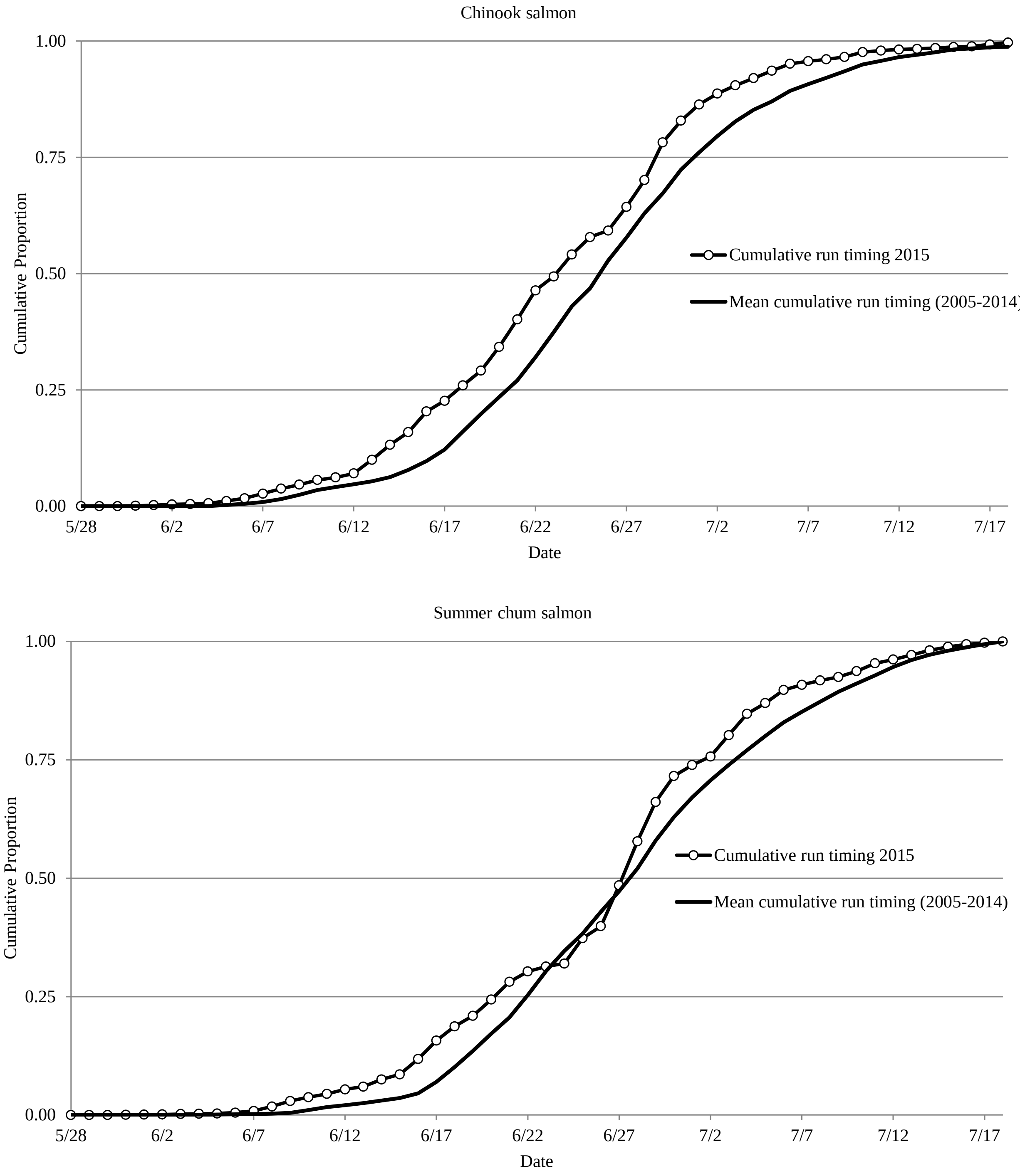


Figure 14.–2015 Chinook and summer chum salmon daily cumulative passage timing compared to the 2005–2014 mean passage timing, at the Pilot Station sonar project on the Yukon River.

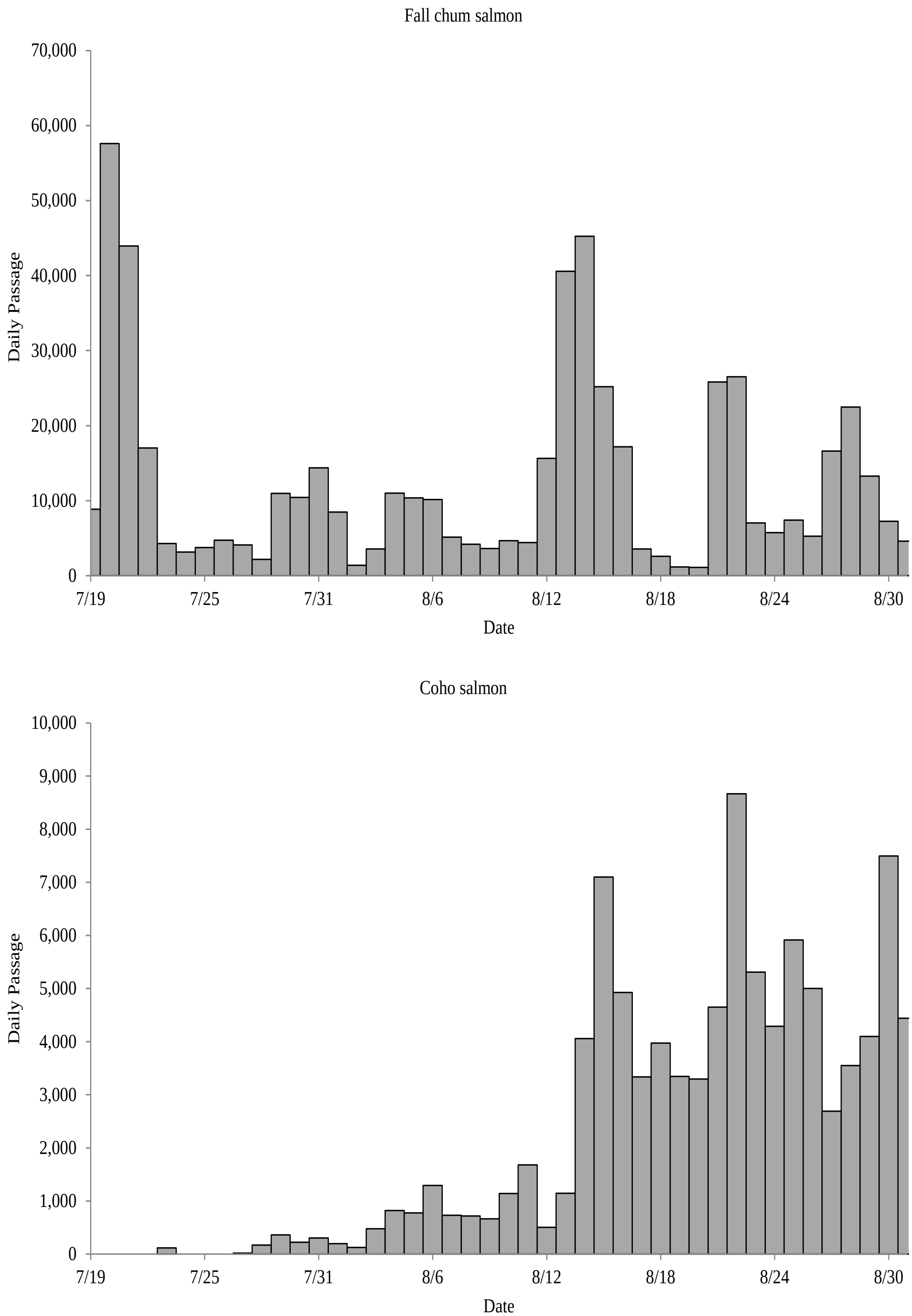
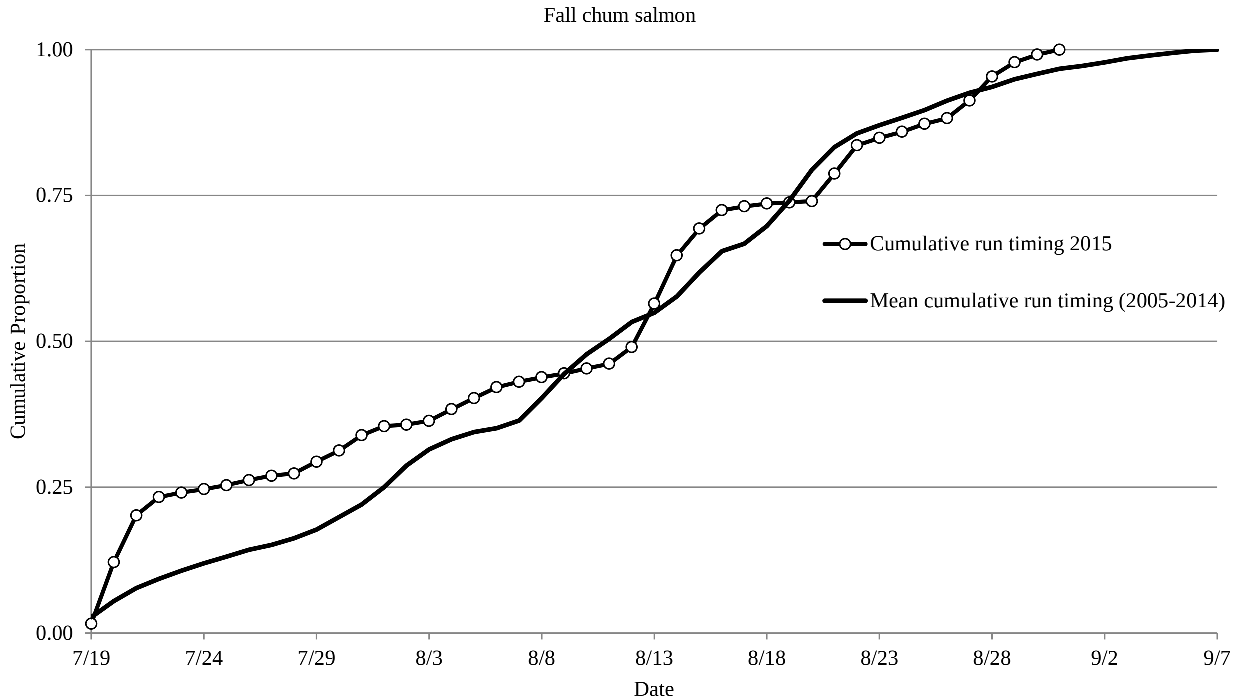


Figure 15.–Fall chum and coho salmon daily passage estimates, at the Pilot Station sonar project on the Yukon River, 2015.



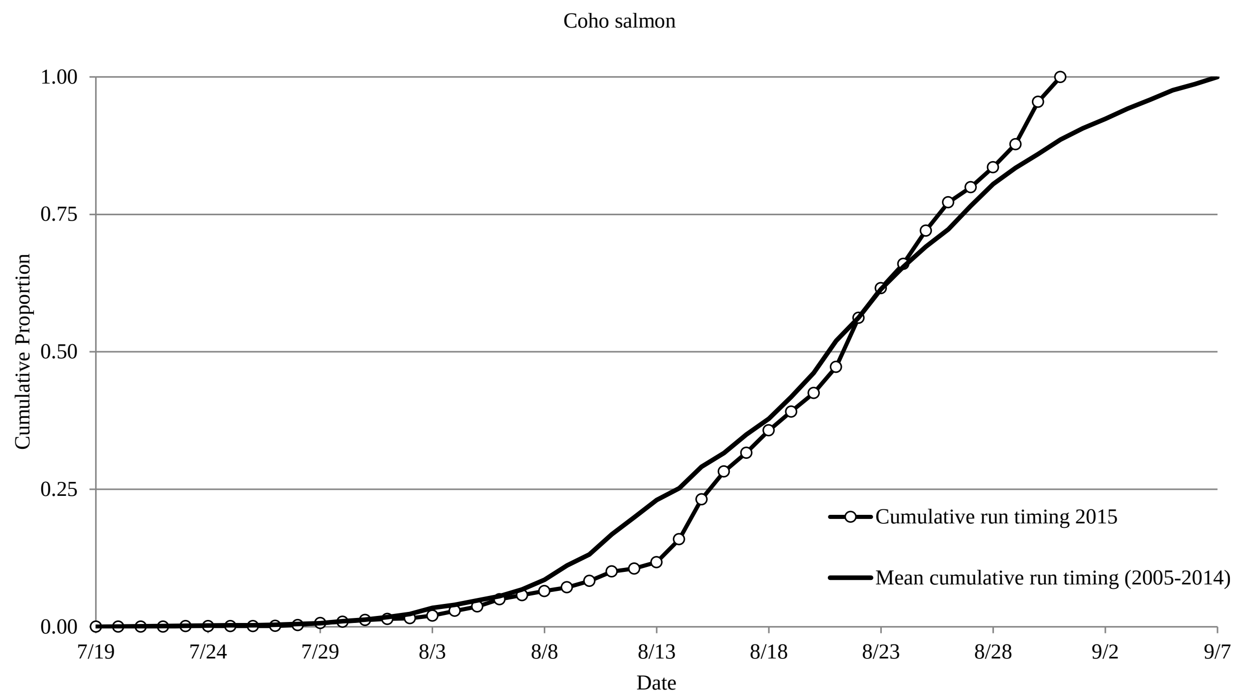


Figure 16.–2015 fall chum and coho salmon daily cumulative passage timing compared to the 2005–2014 mean passage timing, at the Pilot Station sonar project on the Yukon River.

APPENDIX A: NET SELECTIVITY PARAMETERS USED IN FISH SPECIES APPORTIONMENT AT THE PILOT STATION SONAR PROJECT

Appendix A1.–Net selectivity parameters used in species apportionment, at the Pilot Station sonar project on the Yukon River, 2015.

Species	Tau	Sigma	Theta	Lambda	Tangle
Large Chinook [a]	1.9008	0.2050	0.5923	-0.4334	0.0239
Small Chinook [b]	1.9008	0.2050	0.5923	-0.4334	0.0239
Summer chum	1.9699	0.1543	0.7504	-0.4841	0.0000
Fall chum	1.8632	0.2330	1.1954	-1.4361	0.0303
Coho	1.9827	0.3269	0.8686	-1.4557	0.1185
Pink	1.9805	0.2598	1.5542	1.2820	0.1649
Broad whitefish	1.7774	0.2205	1.4018	-1.9341	0.0981
Humpback whitefish	1.9021	0.2320	1.1103	-2.0546	0.0642
Cisco	2.0830	0.2223	1.8771	-1.6381	0.1809
Other [c]	2.2604	0.3642	0.9881	-2.2990	0.0000

[a] Chinook salmon >655 mm.

[b] Chinook salmon ≤655 mm.

[c] Includes sockeye salmon, sheefish, burbot, longnose sucker, Dolly Varden, and northern pike.

APPENDIX B: SALMON SPECIES CPUE BY DAY AND BANK

Appendix B1.–Left bank CPUE, by day and salmon species, at the Pilot Station sonar project on the Yukon River, 2015.

	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	fathom hours	Catch	CPUE	Fathom hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
5/30	17.08	1	0.06	16.39	0	0.00	0	0.00	0	0.00
5/31	20.25	1	0.05	19.97	2	0.10	0	0.00	0	0.00
6/01	18.00	2	0.11	17.21	1	0.06	0	0.00	0	0.00
6/02	17.15	0	0.00	17.46	3	0.17	0	0.00	0	0.00
6/03	17.65	1	0.06	16.85	8	0.47	0	0.00	0	0.00
6/04	17.71	0	0.00	18.21	1	0.05	0	0.00	0	0.00
6/05	16.17	2	0.12	15.88	3	0.19	0	0.00	0	0.00
6/06	17.35	4	0.23	16.89	11	0.65	0	0.00	0	0.00
6/07	17.80	7	0.39	16.73	14	0.84	0	0.00	0	0.00
6/08	16.88	5	0.30	17.23	42	2.44	0	0.00	0	0.00
6/09	16.26	5	0.31	16.78	44	2.62	0	0.00	0	0.00
6/10	17.33	7	0.40	16.66	19	1.14	0	0.00	0	0.00
6/11	15.41	5	0.32	14.74	28	1.90	0	0.00	0	0.00
6/12	16.55	5	0.30	16.44	34	2.07	0	0.00	0	0.00
6/13	17.11	10	0.58	16.44	20	1.22	0	0.00	0	0.00
6/14	17.69	13	0.73	15.69	32	2.04	0	0.00	0	0.00
6/15	16.49	9	0.55	17.52	22	1.26	0	0.00	0	0.00
6/16	14.70	5	0.34	15.94	32	2.01	0	0.00	0	0.00
6/17	17.08	1	0.06	12.40	62	5.00	0	0.00	0	0.00
6/18	16.66	7	0.42	15.15	38	2.51	0	0.00	0	0.00
6/19	17.21	6	0.35	17.31	46	2.66	0	0.00	0	0.00
6/20	16.64	9	0.54	14.89	58	3.89	0	0.00	0	0.00
6/21	17.77	6	0.34	12.07	68	5.64	0	0.00	0	0.00
6/22	17.53	13	0.74	15.08	35	2.32	0	0.00	0	0.00
6/23	16.81	3	0.18	16.77	20	1.19	0	0.00	0	0.00
6/24	16.64	6	0.36	17.29	8	0.46	0	0.00	0	0.00
6/25	15.54	2	0.13	10.61	46	4.34	0	0.00	0	0.00
6/26	17.42	3	0.17	17.76	34	1.91	0	0.00	0	0.00
6/27	15.31	11	0.72	9.01	81	8.99	0	0.00	0	0.00
6/28	16.30	7	0.43	12.41	90	7.25	0	0.00	0	0.00
6/29	15.38	6	0.39	10.31	42	4.07	0	0.00	0	0.00
6/30	15.91	7	0.44	9.33	57	6.11	0	0.00	0	0.00
7/01	15.93	7	0.44	15.50	25	1.61	0	0.00	0	0.00
7/02	17.50	7	0.40	18.16	29	1.60	0	0.00	0	0.00
7/03	17.18	2	0.12	12.11	36	2.97	0	0.00	0	0.00

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Appendix B1.–Page 2 of 3.

Date	Large mesh fathom hours	Chinook		Small mesh Fathom hours	Summer chum		Fall chum		Coho	
		Catch	CPUE		Catch	CPUE	Catch	CPUE	Catch	CPUE
7/04	18.19	3	0.16	17.09	41	2.40	0	0.00	0	0.00
7/05	17.92	3	0.17	16.22	31	1.91	0	0.00	0	0.00
7/06	16.93	2	0.12	15.86	33	2.08	0	0.00	0	0.00
7/07	16.91	2	0.12	16.59	16	0.96	0	0.00	0	0.00
7/08	10.41	1	0.10	9.99	19	1.90	0	0.00	0	0.00
7/09	16.84	2	0.12	17.09	8	0.47	0	0.00	0	0.00
7/10	11.50	2	0.17	11.07	15	1.36	0	0.00	0	0.00
7/11	16.86	0	0.00	16.94	21	1.24	0	0.00	0	0.00
7/12	11.85	0	0.00	11.52	6	0.52	0	0.00	0	0.00
7/13	17.77	0	0.00	17.17	14	0.82	0	0.00	0	0.00
7/14	11.44	0	0.00	11.48	10	0.87	0	0.00	0	0.00
7/15	16.84	0	0.00	16.50	10	0.61	0	0.00	0	0.00
7/16	9.63	0	0.00	9.64	0	0.00	0	0.00	0	0.00
7/17	17.35	2	0.12	16.38	2	0.12	0	0.00	0	0.00
7/18	11.69	0	0.00	11.36	2	0.18	0	0.00	0	0.00
7/19	5.80	0	0.00	18.04	0	0.00	7	0.39	0	0.00
7/20	5.82	0	0.00	15.21	0	0.00	43	2.83	0	0.00
7/21	5.94	0	0.00	9.91	0	0.00	61	6.15	0	0.00
7/22	5.03	0	0.00	10.67	0	0.00	4	0.37	0	0.00
7/23	5.87	0	0.00	17.63	0	0.00	4	0.23	0	0.00
7/24	5.67	0	0.00	17.31	0	0.00	7	0.40	0	0.00
7/25	5.82	0	0.00	17.97	0	0.00	3	0.17	0	0.00
7/26	5.43	0	0.00	11.73	0	0.00	10	0.85	0	0.00
7/27	5.93	0	0.00	17.17	0	0.00	7	0.41	0	0.00
7/28	5.95	0	0.00	17.76	0	0.00	5	0.28	0	0.00
7/29	5.32	0	0.00	16.01	0	0.00	25	1.56	1	0.06
7/30	5.81	0	0.00	16.60	0	0.00	22	1.33	1	0.06
7/31	5.93	0	0.00	16.93	0	0.00	21	1.24	0	0.00
8/01	5.40	0	0.00	11.22	0	0.00	10	0.89	0	0.00
8/02	5.90	0	0.00	17.14	0	0.00	3	0.18	1	0.06
8/03	5.94	0	0.00	18.38	0	0.00	6	0.33	1	0.05
8/04	4.70	0	0.00	11.13	0	0.00	16	1.44	0	0.00
8/05	5.61	0	0.00	17.05	0	0.00	13	0.76	2	0.12
8/06	5.70	0	0.00	17.54	0	0.00	13	0.74	1	0.06
8/07	6.08	0	0.00	16.87	0	0.00	5	0.30	0	0.00

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Appendix B1.–Page 3 of 3.

Date	Large mesh fathom hours	Chinook Catch	Chinook CPUE	Small mesh Fathom hours	Summer chum Catch	Summer chum CPUE	Fall chum Catch	Fall chum CPUE	Coho Catch	Coho CPUE
8/08	5.98	0	0.00	18.24	0	0.00	6	0.33	0	0.00
8/09	5.90	0	0.00	10.91	0	0.00	5	0.46	1	0.09
8/10	5.83	0	0.00	17.41	0	0.00	3	0.17	1	0.06
8/11	5.36	0	0.00	17.81	0	0.00	2	0.11	3	0.17
8/12	5.22	0	0.00	10.51	0	0.00	15	1.43	0	0.00
8/13	5.84	0	0.00	12.93	0	0.00	56	4.33	0	0.00
8/14	5.81	0	0.00	15.13	0	0.00	54	3.57	1	0.07
8/15	5.80	0	0.00	15.80	0	0.00	27	1.71	4	0.25
8/16	5.70	0	0.00	10.77	0	0.00	20	1.86	8	0.74
8/17	6.13	0	0.00	17.44	0	0.00	1	0.06	0	0.00
8/18	5.70	0	0.00	23.60	0	0.00	2	0.08	5	0.21
8/19	5.70	0	0.00	11.64	0	0.00	1	0.09	3	0.26
8/20	0.00	0	0.00	22.66	0	0.00	1	0.04	3	0.13
8/21	5.92	0	0.00	19.74	0	0.00	32	1.62	4	0.20
8/22	5.92	0	0.00	18.14	0	0.00	25	1.38	5	0.28
8/23	5.26	0	0.00	10.81	0	0.00	5	0.46	5	0.46
8/24	5.44	0	0.00	22.89	0	0.00	4	0.17	9	0.39
8/25	5.98	0	0.00	23.17	0	0.00	8	0.35	4	0.17
8/26	5.65	0	0.00	10.68	0	0.00	1	0.09	4	0.37
8/27	6.08	0	0.00	22.76	0	0.00	21	0.92	1	0.04
8/28	4.84	0	0.00	10.76	0	0.00	19	1.77	3	0.28
8/29	5.87	0	0.00	23.25	0	0.00	10	0.43	1	0.04
8/30	5.69	0	0.00	22.49	0	0.00	2	0.09	9	0.40
8/31	4.91	0	0.00	10.16	0	0.00	5	0.49	0	0.00
Total	1,056.70	202	12.16	1,466.06	1,319	97.19	610	42.86	81	5.02

Appendix B2.–Right bank CPUE, by day and salmon species, at the Pilot Station sonar project on the Yukon River, 2015.

	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	fathom hours	Catch	CPUE	Fathom hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
5/30	5.32	0	0.00	0.00	0	0.00	0	0.00	0	0.00
5/31	9.32	0	0.00	0.00	0	0.00	0	0.00	0	0.00
6/01	8.05	0	0.00	1.00	1	0.13	0	0.00	0	0.00
6/02	7.91	0	0.00	0.00	0	0.00	0	0.00	0	0.00
6/03	6.93	0	0.00	3.00	3	0.41	0	0.00	0	0.00
6/04	8.42	0	0.00	2.00	2	0.23	0	0.00	0	0.00
6/05	7.61	0	0.00	0.00	0	0.00	0	0.00	0	0.00
6/06	8.12	1	0.12	3.00	3	0.35	0	0.00	0	0.00
6/07	7.89	1	0.13	4.00	4	0.58	0	0.00	0	0.00
6/08	8.12	1	0.12	7.00	7	0.78	0	0.00	0	0.00
6/09	8.19	0	0.00	11.00	11	1.45	0	0.00	0	0.00
6/10	8.66	0	0.00	7.00	7	0.80	0	0.00	0	0.00
6/11	8.14	0	0.00	17.00	17	2.27	0	0.00	0	0.00
6/12	8.18	0	0.00	4.00	4	0.47	0	0.00	0	0.00
6/13	8.43	0	0.00	3.00	3	0.39	0	0.00	0	0.00
6/14	7.77	0	0.00	16.00	16	1.92	0	0.00	0	0.00
6/15	8.06	2	0.25	10.00	10	1.23	0	0.00	0	0.00
6/16	7.11	0	0.00	29.00	29	3.84	0	0.00	0	0.00
6/17	8.03	1	0.12	31.00	31	4.16	0	0.00	0	0.00
6/18	8.11	1	0.12	18.00	18	3.12	0	0.00	0	0.00
6/19	8.55	3	0.35	11.00	11	1.30	0	0.00	0	0.00
6/20	8.44	2	0.24	7.00	7	0.83	0	0.00	0	0.00
6/21	8.46	1	0.12	9.00	9	1.16	0	0.00	0	0.00
6/22	9.05	2	0.22	11.00	11	1.33	0	0.00	0	0.00
6/23	8.56	0	0.00	12.00	12	1.34	0	0.00	0	0.00
6/24	8.02	1	0.12	1.00	1	0.12	0	0.00	0	0.00
6/25	8.38	0	0.00	20.00	20	3.23	0	0.00	0	0.00
6/26	8.53	0	0.00	15.00	15	1.67	0	0.00	0	0.00
6/27	8.34	1	0.12	21.00	21	3.01	0	0.00	0	0.00
6/28	8.02	1	0.12	58.00	58	8.39	0	0.00	0	0.00
6/29	7.43	2	0.27	28.00	28	5.99	0	0.00	0	0.00
6/30	8.51	3	0.35	42.00	42	6.93	0	0.00	0	0.00
7/01	8.20	1	0.12	34.00	34	4.86	0	0.00	0	0.00
7/02	9.02	0	0.00	24.00	24	2.82	0	0.00	0	0.00
7/03	8.73	1	0.11	50.00	50	7.82	0	0.00	0	0.00

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Appendix B2.–Page 2 of 3.

	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	fathom hours	Catch	CPUE	Fathom hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
7/04	7.60	0	0.00	21.00	21	2.73	0	0.00	0	0.00
7/05	8.79	0	0.00	21.00	21	2.46	0	0.00	0	0.00
7/06	8.20	0	0.00	28.00	28	3.53	0	0.00	0	0.00
7/07	8.47	0	0.00	21.00	21	2.36	0	0.00	0	0.00
7/08	5.24	0	0.00	21.00	21	4.44	0	0.00	0	0.00
7/09	8.61	1	0.12	22.00	22	2.51	0	0.00	0	0.00
7/10	5.59	0	0.00	21.00	21	4.17	0	0.00	0	0.00
7/11	8.45	1	0.12	23.00	23	2.81	0	0.00	0	0.00
7/12	5.76	1	0.17	17.00	17	3.34	0	0.00	0	0.00
7/13	8.77	0	0.00	20.00	20	2.28	0	0.00	0	0.00
7/14	5.93	1	0.17	21.00	21	5.49	0	0.00	0	0.00
7/15	8.63	0	0.00	29.00	29	3.58	0	0.00	0	0.00
7/16	4.85	0	0.00	3.00	3	0.61	0	0.00	0	0.00
7/17	8.45	0	0.00	7.00	7	0.80	0	0.00	0	0.00
7/18	5.61	0	0.00	1.00	1	0.18	0	0.00	0	0.00
7/19	2.92	0	0.00	0.00	0	0.00	15	1.67	0	0.00
7/20	2.30	0	0.00	0.00	0	0.00	51	7.71	0	0.00
7/21	2.20	0	0.00	0.00	0	0.00	29	5.91	0	0.00
7/22	2.68	0	0.00	0.00	0	0.00	6	1.12	0	0.00
7/23	2.99	0	0.00	0.00	0	0.00	5	0.60	0	0.00
7/24	2.50	0	0.00	0.00	0	0.00	3	0.36	0	0.00
7/25	3.01	0	0.00	0.00	0	0.00	3	0.34	0	0.00
7/26	2.50	0	0.00	0.00	0	0.00	6	1.07	0	0.00
7/27	2.75	0	0.00	0.00	0	0.00	6	0.71	0	0.00
7/28	2.84	0	0.00	0.00	0	0.00	10	1.13	2	0.23
7/29	2.64	0	0.00	0.00	0	0.00	14	1.73	3	0.37
7/30	2.89	0	0.00	0.00	0	0.00	20	2.39	1	0.12
7/31	3.07	0	0.00	0.00	0	0.00	23	2.83	1	0.12
8/01	2.57	0	0.00	0.00	0	0.00	12	2.12	0	0.00
8/02	2.95	1	0.34	0.00	0	0.00	6	0.74	0	0.00
8/03	2.77	0	0.00	0.00	0	0.00	8	0.93	0	0.00
8/04	2.91	0	0.00	0.00	0	0.00	28	4.97	0	0.00
8/05	2.95	0	0.00	0.00	0	0.00	16	1.90	3	0.36
8/06	2.95	0	0.00	0.00	0	0.00	18	2.14	4	0.48
8/07	2.97	0	0.00	0.00	0	0.00	10	1.18	6	0.71

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Appendix B2.–Page 3 of 3.

Date	Large mesh fathom hours	Chinook Catch	Chinook CPUE	Small mesh Fathom hours	Summer chum Catch	Summer chum CPUE	Fall chum Catch	Fall chum CPUE	Coho Catch	Coho CPUE
8/08	3.22	0	0.00	0.00	0	0.00	6	0.72	5	0.60
8/09	2.92	0	0.00	0.00	0	0.00	5	0.84	2	0.33
8/10	2.94	0	0.00	0.00	0	0.00	0	0.00	7	0.81
8/11	2.71	0	0.00	0.00	0	0.00	4	0.43	5	0.54
8/12	2.48	0	0.00	0.00	0	0.00	11	2.16	2	0.39
8/13	2.74	0	0.00	0.00	0	0.00	31	4.21	1	0.14
8/14	2.93	0	0.00	0.00	0	0.00	19	2.95	11	1.71
8/15	2.90	0	0.00	0.00	0	0.00	16	2.00	12	1.50
8/16	2.84	0	0.00	0.00	0	0.00	8	1.46	7	1.27
8/17	2.73	0	0.00	0.00	0	0.00	5	0.57	13	1.49
8/18	3.06	0	0.00	0.00	0	0.00	6	0.50	18	1.50
8/19	2.59	0	0.00	0.00	0	0.00	1	0.17	7	1.20
8/20	0.00	0	0.00	0.00	0	0.00	2	0.17	7	0.59
8/21	3.03	0	0.00	0.00	0	0.00	59	6.13	14	1.46
8/22	2.76	0	0.00	0.00	0	0.00	55	7.36	27	3.61
8/23	2.36	0	0.00	0.00	0	0.00	8	1.92	7	1.68
8/24	2.71	0	0.00	0.00	0	0.00	9	0.74	21	1.72
8/25	2.93	0	0.00	0.00	0	0.00	19	1.66	11	0.96
8/26	2.84	0	0.00	0.00	0	0.00	2	0.43	8	1.71
8/27	2.91	0	0.00	0.00	0	0.00	31	2.61	7	0.59
8/28	2.43	0	0.00	0.00	0	0.00	42	7.79	8	1.48
8/29	2.85	0	0.00	0.00	0	0.00	20	1.82	21	1.91
8/30	2.72	0	0.00	0.00	0	0.00	17	1.54	24	2.18
8/31	2.43	0	0.00	0.00	0	0.00	3	0.61	8	1.63
Total	512.95	30	3.92	785.00	785	114.22	668	90.34	273	33.39

APPENDIX C: DAILY FISH PASSAGE ESTIMATES BY ZONE WITH STANDARD ERRORS

Appendix C1.–Daily fish passage estimates by zone with standard errors (SE), at the Pilot Station sonar project on the Yukon River, 2015.

		Left bank		Total		Percent by Bank	
Date	Right bank	Nearshore	Offshore	Passage	SE	Right	Left
5/30	2,112	0	0	2,112	344	100.0	0.0
5/31	3,201	3,828	200	7,229	661	44.3	55.7
6/01	3,545	3,964	259	7,768	801	45.6	54.4
6/02	3,693	2,117	471	6,281	746	58.8	41.2
6/03	3,962	2,253	590	6,805	753	58.2	41.8
6/04	4,493	2,038	334	6,865	840	65.5	34.6
6/05	4,001	2,689	838	7,528	1,959	53.2	46.9
6/06	4,006	2,669	339	7,014	895	57.1	42.9
6/07	3,637	6,781	598	11,016	2,378	33.0	67.0
6/08	3,809	13,291	1,319	18,419	1,582	20.7	79.3
6/09	6,164	12,740	1,875	20,779	3,146	29.7	70.3
6/10	6,271	11,198	1,959	19,428	3,772	32.3	67.7
6/11	5,924	13,677	2,499	22,100	8,296	26.8	73.2
6/12	4,167	8,726	3,567	16,460	1,863	25.3	74.7
6/13	5,748	6,994	4,171	16,913	3,797	34.0	66.0
6/14	6,667	12,321	7,039	26,027	2,166	25.6	74.4
6/15	8,600	10,114	7,915	26,629	4,071	32.3	67.7
6/16	12,459	17,916	21,030	51,405	6,352	24.2	75.8
6/17	17,357	17,117	24,837	59,311	6,734	29.3	70.7
6/18	13,930	15,729	17,948	47,607	4,477	29.3	70.7
6/19	12,093	14,757	13,810	40,660	13,572	29.7	70.3
6/20	9,358	22,461	23,710	55,529	6,877	16.9	83.2
6/21	11,236	20,871	33,163	65,270	13,914	17.2	82.8
6/22	10,238	13,448	21,398	45,084	6,222	22.7	77.3
6/23	7,996	8,395	12,687	29,078	2,869	27.5	72.5
6/24	7,579	8,586	8,267	24,432	6,858	31.0	69.0
6/25	16,031	29,320	45,941	91,292	10,946	17.6	82.4
6/26	12,976	13,644	27,923	54,543	11,482	23.8	76.2
6/27	40,831	48,100	74,890	163,821	19,506	24.9	75.1
6/28	44,087	47,060	70,674	161,821	33,406	27.2	72.8
6/29	38,509	48,724	71,478	158,711	44,288	24.3	75.7
6/30	24,916	31,134	53,661	109,711	24,564	22.7	77.3
7/01	18,459	19,017	22,684	60,160	10,365	30.7	69.3
7/02	18,739	11,341	15,282	45,362	12,961	41.3	58.7
7/03	28,680	26,479	42,683	97,842	15,493	29.3	70.7
7/04	20,120	21,688	30,569	72,377	10,667	27.8	72.2
7/05	19,805	15,667	22,540	58,012	14,244	34.1	65.9
7/06	19,898	15,909	19,459	55,266	10,979	36.0	64.0
7/07	14,746	12,629	9,563	36,938	8,208	39.9	60.1
7/08	14,011	17,523	6,888	38,422	8,897	36.5	63.5
7/09	12,132	12,171	5,481	29,784	5,492	40.7	59.3
7/10	15,582	13,528	15,678	44,788	7,395	34.8	65.2
7/11	17,513	16,181	19,409	53,103	8,279	33.0	67.0
7/12	10,757	10,199	7,022	27,978	5,653	38.5	61.6
7/13	14,578	15,961	11,855	42,394	6,569	34.4	65.6
7/14	17,431	15,336	11,203	43,970	6,914	39.6	60.4
7/15	11,459	13,620	7,823	32,902	6,637	34.8	65.2
7/16	10,103	8,561	4,095	22,759	5,713	44.4	55.6
7/17	8,357	11,579	4,576	24,512	3,284	34.1	65.9

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Appendix C1.–Page 2 of 2.

Date	Right bank	Left bank Nearshore	Left bank Offshore	Total Passage	Total SE	Percent by bank Right	Percent by bank Left
7/18	6,751	11,263	5,350	23,364	3,436	28.9	71.1
7/19	8,230	10,671	6,579	25,480	5,041	32.3	67.7
7/20	16,928	22,866	29,499	69,293	9,544	24.4	75.6
7/21	23,201	27,619	22,835	73,655	17,909	31.5	68.5
7/22	9,932	10,452	8,180	28,564	11,124	34.8	65.2
7/23	6,625	7,415	4,048	18,088	2,110	36.6	63.4
7/24	5,231	6,526	2,648	14,405	2,098	36.3	63.7
7/25	4,824	7,103	2,884	14,811	4,820	32.6	67.4
7/26	6,728	6,052	4,694	17,474	4,553	38.5	61.5
7/27	6,115	8,488	4,693	19,296	2,862	31.7	68.3
7/28	5,547	8,787	3,770	18,104	3,970	30.6	69.4
7/29	9,004	11,853	9,436	30,293	6,641	29.7	70.3
7/30	8,218	13,578	14,106	35,902	4,020	22.9	77.1
7/31	6,935	13,698	14,034	34,667	3,518	20.0	80.0
8/01	5,731	8,922	7,519	22,172	2,790	25.9	74.2
8/02	5,272	8,487	4,331	18,090	3,152	29.1	70.9
8/03	6,684	9,452	6,898	23,034	4,958	29.0	71.0
8/04	12,905	11,515	12,987	37,407	7,313	34.5	65.5
8/05	12,470	11,805	12,036	36,311	7,209	34.3	65.7
8/06	7,714	11,568	10,578	29,860	5,159	25.8	74.2
8/07	5,381	7,332	3,625	16,338	2,319	32.9	67.1
8/08	4,711	6,571	3,721	15,003	2,360	31.4	68.6
80/9	4,835	4,968	3,187	12,990	2,189	37.2	62.8
8/10	5,252	4,818	3,065	13,135	2,566	40.0	60.0
8/11	5,394	4,647	2,895	12,936	3,707	41.7	58.3
8/12	6,879	5,547	8,346	20,772	3,157	33.1	66.9
8/13	12,421	10,356	28,068	50,845	4,759	24.4	75.6
8/14	12,586	14,903	32,539	60,028	5,013	21.0	79.0
8/15	9,823	9,315	22,035	41,173	5,324	23.9	76.1
8/16	7,251	8,067	13,482	28,800	4,529	25.2	74.8
8/17	7,463	5,766	7,251	20,480	5,434	36.4	63.6
8/18	6,260	3,107	3,257	12,624	2,862	49.6	50.4
8/19	5,403	3,528	2,675	11,606	1,753	46.6	53.5
8/20	5,993	3,109	2,589	11,691	1,733	51.3	48.7
8/21	21,431	8,288	20,795	50,514	12,185	42.4	57.6
8/22	21,071	12,686	25,444	59,201	9,063	35.6	64.4
8/23	10,743	6,164	9,579	26,486	6,489	40.6	59.4
8/24	7,725	5,269	8,090	21,084	5,719	36.6	63.4
8/25	7,467	6,390	9,323	23,180	5,528	32.2	67.8
8/26	7,702	3,656	4,789	16,147	4,269	47.7	52.3
8/27	12,762	4,862	10,791	28,415	5,886	44.9	55.1
8/28	14,238	8,433	15,608	38,279	6,735	37.2	62.8
8/29	12,698	4,311	12,147	29,156	5,422	43.6	56.5
8/30	12,683	3,882	6,712	23,277	4,029	54.5	45.5
8/31	6,281	3,354	4,421	14,056	3,179	44.7	55.3
Season	1,041,464	1,117,500	1,263,739	3,422,703	90,120	30.4	69.6

APPENDIX D: DAILY FISH PASSAGE ESTIMATES BY SPECIES

Appendix D1.–Daily fish passage estimates by species, at the Pilot Station sonar project on the Yukon River, 2015.

	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other[c]	Total
5/30	0	0	0	68	0	0	0	2,044	2,112
5/31	80	0	80	263	0	0	0	6,886	7,229
6/01	20	152	172	541	0	0	0	7,055	7,768
6/02	96	80	176	636	0	0	0	5,469	6,281
6/03	108	0	108	1,488	0	0	0	5,209	6,805
6/04	190	0	190	487	0	0	0	6,188	6,865
6/05	548	0	548	923	0	0	0	6,057	7,528
6/06	543	143	686	2,584	0	0	0	3,744	7,014
6/07	1,178	0	1,178	4,784	0	0	0	5,054	11,016
6/08	1,066	162	1,228	13,103	0	0	0	4,088	18,419
6/09	675	324	999	16,055	0	0	0	3,725	20,779
6/10	923	242	1,165	11,245	0	0	0	7,018	19,428
6/11	496	129	625	9,556	0	0	0	11,919	22,100
6/12	999	0	999	13,265	0	0	0	2,196	16,460
6/13	3,405	0	3,405	8,113	0	0	0	5,395	16,913
6/14	3,771	0	3,771	21,013	0	0	0	1,243	26,027
6/15	3,139	0	3,139	14,605	0	0	0	8,885	26,629
6/16	3,528	1,636	5,164	44,817	0	0	0	1,424	51,405
6/17	2,220	448	2,668	53,854	0	0	0	2,789	59,311
6/18	3,588	231	3,819	41,737	0	0	0	2,051	47,607
6/19	3,201	509	3,710	30,964	0	0	0	5,986	40,660
6/20	3,871	2,064	5,935	47,531	0	0	0	2,063	55,529
6/21	4,415	2,405	6,820	51,952	0	0	0	6,498	65,270
6/22	5,266	1,992	7,258	30,142	0	0	0	7,684	45,084
6/23	2,179	1,327	3,506	14,607	0	0	0	10,965	29,078
6/24	3,533	1,943	5,476	8,583	0	0	0	10,373	24,432
6/25	2,773	1,568	4,341	74,000	0	0	0	12,951	91,292
6/26	1,191	428	1,619	35,384	0	0	0	17,540	54,543
6/27	5,466	467	5,933	119,526	0	0	0	38,362	163,821
6/28	3,799	2,867	6,666	128,217	0	0	0	26,938	161,821
6/29	6,487	2,933	9,420	115,605	0	0	0	33,686	158,711
6/30	3,841	1,561	5,402	75,843	0	0	0	28,466	109,711
7/01	2,569	1,482	4,051	32,134	0	0	0	23,975	60,160
7/02	2,168	540	2,708	25,054	0	0	0	17,600	45,362
7/03	1,625	454	2,079	62,264	0	0	0	33,499	97,842
7/04	1,357	419	1,776	62,499	0	915	0	7,187	72,377
7/05	1,035	823	1,858	31,338	0	0	0	24,816	58,012
7/06	1,185	555	1,740	38,349	0	366	0	14,811	55,266
7/07	348	279	627	15,049	0	0	0	21,262	36,938
7/08	271	216	487	12,776	0	0	0	25,159	38,422
7/09	512	93	605	10,074	0	553	0	18,552	29,784
7/10	970	218	1,188	17,123	0	647	0	25,830	44,788
7/11	284	116	400	22,835	0	142	0	29,726	53,103
7/12	174	71	245	11,213	0	87	0	16,433	27,978
7/13	75	95	170	13,143	0	508	0	28,573	42,394
7/14	90	113	203	13,780	0	516	0	29,471	43,970
7/15	268	0	268	10,222	0	124	0	22,288	32,902
7/16	166	0	166	7,399	0	110	0	15,084	22,759
7/17	363	98	461	4,238	0	575	0	19,238	24,512

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Appendix D1.–Page 2 of 2.

	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other[c]	Total
7/18	393	79	472	4,102	0	560	0	18,230	23,364
7/19	0	0	0	0	8,869	927	0	15,684	25,480
7/20	0	0	0	0	57,605	210	0	11,478	69,293
7/21	0	0	0	0	43,934	964	0	28,757	73,655
7/22	0	0	0	0	17,042	364	0	11,158	28,564
7/23	0	0	0	0	4,288	0	115	13,685	18,088
7/24	0	0	0	0	3,166	242	0	10,997	14,405
7/25	0	68	68	0	3,751	759	0	10,233	14,811
7/26	0	111	111	0	4,725	647	0	11,991	17,474
7/27	0	23	23	0	4,101	546	18	14,608	19,296
7/28	0	0	0	0	2,189	1,098	168	14,649	18,104
7/29	0	0	0	0	10,973	433	360	18,527	30,293
7/30	0	0	0	0	10,432	621	223	24,626	35,902
7/31	0	0	0	0	14,376	1,887	304	18,100	34,667
8/01	0	0	0	0	8,498	1,200	198	12,276	22,172
8/02	64	0	64	0	1,407	1,154	124	15,341	18,090
8/03	0	0	0	0	3,570	1,488	477	17,499	23,034
8/04	0	0	0	0	10,994	1,190	820	24,403	37,407
8/05	0	0	0	0	10,382	1,220	777	23,932	36,311
8/06	0	0	0	0	10,161	439	1,291	17,969	29,860
8/07	0	0	0	0	5,131	0	730	10,477	16,338
8/08	0	0	0	0	4,199	226	720	9,858	15,003
8/09	0	0	0	0	3,640	171	663	8,516	12,990
8/10	0	0	0	0	4,673	0	1,143	7,319	13,135
8/11	0	0	0	0	4,432	567	1,680	6,257	12,936
8/12	0	0	0	0	15,638	0	503	4,631	20,772
8/13	0	0	0	0	40,584	0	1,146	9,115	50,845
8/14	0	0	0	0	45,255	271	4,056	10,446	60,028
8/15	0	0	0	0	25,197	0	7,098	8,878	41,173
8/16	0	0	0	0	17,201	0	4,925	6,674	28,800
8/17	108	0	108	0	3,569	59	3,336	13,408	20,480
8/18	0	0	0	0	2,607	0	3,972	6,045	12,624
8/19	0	0	0	0	1,174	229	3,343	6,860	11,606
8/20	0	0	0	0	1,115	202	3,294	7,080	11,691
8/21	0	0	0	0	25,807	0	4,652	20,055	50,514
8/22	0	0	0	0	26,511	0	8,668	24,022	59,201
8/23	0	0	0	0	7,031	0	5,308	14,147	26,486
8/24	0	0	0	0	5,753	0	4,291	11,040	21,084
8/25	0	0	0	0	7,406	0	5,914	9,860	23,180
8/26	0	0	0	0	5,283	0	5,000	5,864	16,147
8/27	0	0	0	0	16,629	75	2,689	9,022	28,415
8/28	0	0	0	0	22,468	129	3,552	12,130	38,279
8/29	0	0	0	0	13,281	0	4,096	11,779	29,156
8/30	0	0	0	0	7,252	0	7,494	8,531	23,277
8/31	0	0	0	0	4,595	0	4,439	5,022	14,056
Total	86,620	29,464	116,084	1,385,083	546,894	22,421	97,587	1,254,634	3,422,703

[a] Chinook salmon >655 mm.

[b] Chinook salmon ≤655 mm.

[c] Includes sockeye salmon, cisco, whitefish, sheefish, burbot, longnose sucker, Dolly Varden, and northern pike.

APPENDIX E: DAILY CUMULATIVE FISH PASSAGE ESTIMATES, PROPORTIONS, AND TIMING BY SPECIES

Appendix E1.–Daily cumulative fish passage proportions and timing by species, at the Pilot Station sonar project on the Yukon River, 2015.

	Chinook			Chum					
Date	Large [a]	Small [b]	Total	Summer	Fall	Pink	Coho	Other [c]	Total
5/30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
6/01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
6/02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.01
6/03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.01
6/04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.01
6/05	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.01
6/06	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.03	0.02
6/07	0.03	0.01	0.03	0.01	0.00	0.00	0.00	0.04	0.02
6/08	0.04	0.02	0.04	0.02	0.00	0.00	0.00	0.04	0.02
6/09	0.05	0.03	0.05	0.03	0.00	0.00	0.00	0.04	0.03
6/10	0.06	0.04	0.06	0.04	0.00	0.00	0.00	0.05	0.04
6/11	0.07	0.04	0.06	0.04	0.00	0.00	0.00	0.06	0.04
6/12	0.08	0.04	0.07	0.05	0.00	0.00	0.00	0.06	0.05
6/13	0.12	0.04	0.10	0.06	0.00	0.00	0.00	0.07	0.05
6/14	0.16	0.04	0.13	0.08	0.00	0.00	0.00	0.07	0.06
6/15	0.20	0.04	0.16	0.09	0.00	0.00	0.00	0.07	0.07
6/16	0.24	0.10	0.20	0.12	0.00	0.00	0.00	0.07	0.08
6/17	**0.27**	0.11	0.23	0.16	0.00	0.00	0.00	0.08	0.10
6/18	0.31	0.12	**0.26**	0.19	0.00	0.00	0.00	0.08	0.11
6/19	0.34	0.14	0.29	0.21	0.00	0.00	0.00	0.08	0.13
6/20	0.39	0.21	0.34	0.24	0.00	0.00	0.00	0.08	0.14
6/21	0.44	**0.29**	0.40	**0.28**	0.00	0.00	0.00	0.09	0.16
6/22	**0.50**	0.36	0.46	0.30	0.00	0.00	0.00	0.10	0.17
6/23	0.53	0.40	0.49	0.31	0.00	0.00	0.00	0.10	0.18
6/24	0.57	0.47	**0.54**	0.32	0.00	0.00	0.00	0.11	0.19
6/25	0.60	**0.52**	0.58	0.37	0.00	0.00	0.00	0.12	0.22
6/26	0.61	0.54	0.59	0.40	0.00	0.00	0.00	0.14	0.23
6/27	0.67	0.55	0.64	0.49	0.00	0.00	0.00	0.17	**0.28**
6/28	0.72	0.65	0.70	**0.58**	0.00	0.00	0.00	0.19	0.33
6/29	**0.79**	**0.75**	**0.78**	0.66	0.00	0.00	0.00	0.22	0.37
6/30	0.84	0.80	0.83	0.72	0.00	0.00	0.00	0.24	0.41
7/01	0.87	0.85	0.86	0.74	0.00	0.00	0.00	**0.26**	0.42
7/02	0.89	0.87	0.89	**0.76**	0.00	0.00	0.00	0.27	0.44
7/03	0.91	0.89	0.90	0.80	0.00	0.00	0.00	0.30	0.46
7/04	0.93	0.90	0.92	0.85	0.00	0.04	0.00	0.30	0.49
7/05	0.94	0.93	0.94	0.87	0.00	0.04	0.00	0.32	**0.50**
7/06	0.95	0.95	0.95	0.90	0.00	0.06	0.00	0.34	0.52
7/07	0.96	0.96	0.96	0.91	0.00	0.06	0.00	0.35	0.53
7/08	0.96	0.96	0.96	0.92	0.00	0.06	0.00	0.37	0.54
7/09	0.97	0.97	0.97	0.92	0.00	0.08	0.00	0.39	0.55
7/10	0.98	0.97	0.98	0.94	0.00	0.11	0.00	0.41	0.56
7/11	0.98	0.98	0.98	0.95	0.00	0.12	0.00	0.43	0.58
7/12	0.98	0.98	0.98	0.96	0.00	0.12	0.00	0.45	0.59
7/13	0.98	0.98	0.98	0.97	0.00	0.14	0.00	0.47	0.60
7/14	0.98	0.99	0.99	0.98	0.00	0.17	0.00	0.49	0.61
7/15	0.99	0.99	0.99	0.99	0.00	0.17	0.00	**0.51**	0.62
7/16	0.99	0.99	0.99	0.99	0.00	0.18	0.00	0.52	0.63
7/17	0.99	0.99	0.99	1.00	0.00	0.20	0.00	0.54	0.64

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Appendix E1.–Page 2 of 2.

Date	Chinook			Chum		Pink	Coho	Other [c]	Total
	Large [a]	Small [b]	Total	Summer	Fall				
7/18	1.00	0.99	1.00	1.00	0.00	0.23	0.00	0.55	0.64
7/19	1.00	0.99	1.00	1.00	0.02	**0.27**	0.00	0.56	0.65
7/20	1.00	0.99	1.00	1.00	0.12	0.28	0.00	0.57	0.67
7/21	1.00	0.99	1.00	1.00	0.20	0.32	0.00	0.60	0.69
7/22	1.00	0.99	1.00	1.00	0.23	0.34	0.00	0.60	0.70
7/23	1.00	0.99	1.00	1.00	0.24	0.34	0.00	0.62	0.70
7/24	1.00	0.99	1.00	1.00	**0.25**	0.35	0.00	0.62	0.71
7/25	1.00	1.00	1.00	1.00	0.25	0.38	0.00	0.63	0.71
7/26	1.00	1.00	1.00	1.00	0.26	0.41	0.00	0.64	0.72
7/27	1.00	1.00	1.00	1.00	0.27	0.44	0.00	0.65	0.72
7/28	1.00	1.00	1.00	1.00	0.27	0.48	0.00	0.67	0.73
7/29	1.00	1.00	1.00	1.00	0.29	**0.50**	0.01	0.68	0.74
7/30	1.00	1.00	1.00	1.00	0.31	0.53	0.01	0.70	**0.75**
7/31	1.00	1.00	1.00	1.00	0.34	0.62	0.01	0.71	0.76
8/01	1.00	1.00	1.00	1.00	0.35	0.67	0.01	0.72	0.77
8/02	1.00	1.00	1.00	1.00	0.36	0.72	0.02	0.74	0.77
8/03	1.00	1.00	1.00	1.00	0.36	**0.79**	0.02	**0.75**	0.78
8/04	1.00	1.00	1.00	1.00	0.38	0.84	0.03	0.77	0.79
8/05	1.00	1.00	1.00	1.00	0.40	0.89	0.04	0.79	0.80
8/06	1.00	1.00	1.00	1.00	0.42	0.91	0.05	0.80	0.81
8/07	1.00	1.00	1.00	1.00	0.43	0.91	0.06	0.81	0.81
8/08	1.00	1.00	1.00	1.00	0.44	0.92	0.06	0.82	0.82
8/09	1.00	1.00	1.00	1.00	0.45	0.93	0.07	0.83	0.82
8/10	1.00	1.00	1.00	1.00	0.45	0.93	0.08	0.83	0.82
8/11	1.00	1.00	1.00	1.00	0.46	0.96	0.10	0.84	0.83
8/12	1.00	1.00	1.00	1.00	0.49	0.96	0.11	0.84	0.83
8/13	1.00	1.00	1.00	1.00	**0.56**	0.96	0.12	0.85	0.85
8/14	1.00	1.00	1.00	1.00	0.65	0.97	0.16	0.86	0.87
8/15	1.00	1.00	1.00	1.00	0.69	0.97	0.23	0.86	0.88
8/16	1.00	1.00	1.00	1.00	0.72	0.97	**0.28**	0.87	0.89
8/17	1.00	1.00	1.00	1.00	0.73	0.97	0.32	0.88	0.89
8/18	1.00	1.00	1.00	1.00	0.74	0.97	0.36	0.88	0.90
8/19	1.00	1.00	1.00	1.00	0.74	0.98	0.39	0.89	0.90
8/20	1.00	1.00	1.00	1.00	0.74	0.99	0.43	0.90	0.90
8/21	1.00	1.00	1.00	1.00	**0.79**	0.99	0.47	0.91	0.92
8/22	1.00	1.00	1.00	1.00	0.84	0.99	**0.56**	0.93	0.94
8/23	1.00	1.00	1.00	1.00	0.85	0.99	0.62	0.94	0.94
8/24	1.00	1.00	1.00	1.00	0.86	0.99	0.66	0.95	0.95
8/25	1.00	1.00	1.00	1.00	0.87	0.99	0.72	0.96	0.96
8/26	1.00	1.00	1.00	1.00	0.88	0.99	**0.77**	0.96	0.96
8/27	1.00	1.00	1.00	1.00	0.91	0.99	0.80	0.97	0.97
8/28	1.00	1.00	1.00	1.00	0.95	1.00	0.84	0.98	0.98
8/29	1.00	1.00	1.00	1.00	0.98	1.00	0.88	0.99	0.99
8/30	1.00	1.00	1.00	1.00	0.99	1.00	0.95	1.00	1.00
8/31	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: The 25th, 50th, and 75th percentiles are in bold.

[a] Chinook salmon >655 mm.

[b] Chinook salmon ≤655 mm.

[c] Includes sockeye salmon, cisco, whitefish, sheefish, burbot, longnose sucker, Dolly Varden, and northern pike.

Appendix E2.–Daily cumulative fish passage estimates by species, at the Pilot Station sonar project on the Yukon River, 2015.

	Chinook			Chum					
Date	Large [a]	Small [b]	Total	Summer	Fall	Coho	Pink	Other [c]	Total
5/30	0	0	0	68	0	0	0	2,044	2,112
5/31	80	0	80	331	0	0	0	8,930	9,341
6/01	100	152	252	872	0	0	0	15,985	17,109
6/02	196	232	428	1,508	0	0	0	21,454	23,390
6/03	304	232	536	2,996	0	0	0	26,663	30,195
6/04	494	232	726	3,483	0	0	0	32,851	37,060
6/05	1,042	232	1,274	4,406	0	0	0	38,908	44,588
6/06	1,585	375	1,960	6,990	0	0	0	42,652	51,602
6/07	2,763	375	3,138	11,774	0	0	0	47,706	62,618
6/08	3,829	537	4,366	24,877	0	0	0	51,794	81,037
6/09	4,504	861	5,365	40,932	0	0	0	55,519	101,816
6/10	5,427	1,103	6,530	52,177	0	0	0	62,537	121,244
6/11	5,923	1,232	7,155	61,733	0	0	0	74,456	143,344
6/12	6,922	1,232	8,154	74,998	0	0	0	76,652	159,804
6/13	10,327	1,232	11,559	83,111	0	0	0	82,047	176,717
6/14	14,098	1,232	15,330	104,124	0	0	0	83,290	202,744
6/15	17,237	1,232	18,469	118,729	0	0	0	92,175	229,373
6/16	20,765	2,868	23,633	163,546	0	0	0	93,599	280,778
6/17	22,985	3,316	26,301	217,400	0	0	0	96,388	340,089
6/18	26,573	3,547	30,120	259,137	0	0	0	98,439	387,696
6/19	29,774	4,056	33,830	290,101	0	0	0	104,425	428,356
6/20	33,645	6,120	39,765	337,632	0	0	0	106,488	483,885
6/21	38,060	8,525	46,585	389,584	0	0	0	112,986	549,155
6/22	43,326	10,517	53,843	419,726	0	0	0	120,670	594,239
6/23	45,505	11,844	57,349	434,333	0	0	0	131,635	623,317
6/24	49,038	13,787	62,825	442,916	0	0	0	142,008	647,749
6/25	51,811	15,355	67,166	516,916	0	0	0	154,959	739,041
6/26	53,002	15,783	68,785	552,300	0	0	0	172,499	793,584
6/27	58,468	16,250	74,718	671,826	0	0	0	210,861	957,405
6/28	62,267	19,117	81,384	800,043	0	0	0	237,799	1,119,226
6/29	68,754	22,050	90,804	915,648	0	0	0	271,485	1,277,937
6/30	72,595	23,611	96,206	991,491	0	0	0	299,951	1,387,648
7/01	75,164	25,093	100,257	1,023,625	0	0	0	323,926	1,447,808
7/02	77,332	25,633	102,965	1,048,679	0	0	0	341,526	1,493,170
7/03	78,957	26,087	105,044	1,110,943	0	0	0	375,025	1,591,012
7/04	80,314	26,506	106,820	1,173,442	0	0	915	382,212	1,663,389
7/05	81,349	27,329	108,678	1,204,780	0	0	915	407,028	1,721,401
7/06	82,534	27,884	110,418	1,243,129	0	0	1,281	421,839	1,776,667
7/07	82,882	28,163	111,045	1,258,178	0	0	1,281	443,101	1,813,605
7/08	83,153	28,379	111,532	1,270,954	0	0	1,281	468,260	1,852,027
7/09	83,665	28,472	112,137	1,281,028	0	0	1,834	486,812	1,881,811
7/10	84,635	28,690	113,325	1,298,151	0	0	2,481	512,642	1,926,599
7/11	84,919	28,806	113,725	1,320,986	0	0	2,623	542,368	1,979,702
7/12	85,093	28,877	113,970	1,332,199	0	0	2,710	558,801	2,007,680
7/13	85,168	28,972	114,140	1,345,342	0	0	3,218	587,374	2,050,074
7/14	85,258	29,085	114,343	1,359,122	0	0	3,734	616,845	2,094,044
7/15	85,526	29,085	114,611	1,369,344	0	0	3,858	639,133	2,126,946
7/16	85,692	29,085	114,777	1,376,743	0	0	3,968	654,217	2,149,705
7/17	86,055	29,183	115,238	1,380,981	0	0	4,543	673,455	2,174,217

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Appendix E2.–Page 2 of 2.

Date	Chinook			Chum		Coho	Pink	Other [c]	Total
	Large [a]	Small [b]	Total	Summer	Fall				
7/18	86,448	29,262	115,710	1,385,083	0	0	5,103	691,685	2,197,581
7/19	86,448	29,262	115,710	1,385,083	8,869	0	6,030	707,369	2,223,061
7/20	86,448	29,262	115,710	1,385,083	66,474	0	6,240	718,847	2,292,354
7/21	86,448	29,262	115,710	1,385,083	110,408	0	7,204	747,604	2,366,009
7/22	86,448	29,262	115,710	1,385,083	127,450	0	7,568	758,762	2,394,573
7/23	86,448	29,262	115,710	1,385,083	131,738	115	7,568	772,447	2,412,661
7/24	86,448	29,262	115,710	1,385,083	134,904	115	7,810	783,444	2,427,066
7/25	86,448	29,330	115,778	1,385,083	138,655	115	8,569	793,677	2,441,877
7/26	86,448	29,441	115,889	1,385,083	143,380	115	9,216	805,668	2,459,351
7/27	86,448	29,464	115,912	1,385,083	147,481	133	9,762	820,276	2,478,647
7/28	86,448	29,464	115,912	1,385,083	149,670	301	10,860	834,925	2,496,751
7/29	86,448	29,464	115,912	1,385,083	160,643	661	11,293	853,452	2,527,044
7/30	86,448	29,464	115,912	1,385,083	171,075	884	11,914	878,078	2,562,946
7/31	86,448	29,464	115,912	1,385,083	185,451	1,188	13,801	896,178	2,597,613
8/01	86,448	29,464	115,912	1,385,083	193,949	1,386	15,001	908,454	2,619,785
8/02	86,512	29,464	115,976	1,385,083	195,356	1,510	16,155	923,795	2,637,875
8/03	86,512	29,464	115,976	1,385,083	198,926	1,987	17,643	941,294	2,660,909
8/04	86,512	29,464	115,976	1,385,083	209,920	2,807	18,833	965,697	2,698,316
8/05	86,512	29,464	115,976	1,385,083	220,302	3,584	20,053	989,629	2,734,627
8/06	86,512	29,464	115,976	1,385,083	230,463	4,875	20,492	1,007,598	2,764,487
8/07	86,512	29,464	115,976	1,385,083	235,594	5,605	20,492	1,018,075	2,780,825
8/08	86,512	29,464	115,976	1,385,083	239,793	6,325	20,718	1,027,933	2,795,828
8/09	86,512	29,464	115,976	1,385,083	243,433	6,988	20,889	1,036,449	2,808,818
8/10	86,512	29,464	115,976	1,385,083	248,106	8,131	20,889	1,043,768	2,821,953
8/11	86,512	29,464	115,976	1,385,083	252,538	9,811	21,456	1,050,025	2,834,889
8/12	86,512	29,464	115,976	1,385,083	268,176	10,314	21,456	1,054,656	2,855,661
8/13	86,512	29,464	115,976	1,385,083	308,760	11,460	21,456	1,063,771	2,906,506
8/14	86,512	29,464	115,976	1,385,083	354,015	15,516	21,727	1,074,217	2,966,534
8/15	86,512	29,464	115,976	1,385,083	379,212	22,614	21,727	1,083,095	3,007,707
8/16	86,512	29,464	115,976	1,385,083	396,413	27,539	21,727	1,089,769	3,036,507
8/17	86,620	29,464	116,084	1,385,083	399,982	30,875	21,786	1,103,177	3,056,987
8/18	86,620	29,464	116,084	1,385,083	402,589	34,847	21,786	1,109,222	3,069,611
8/19	86,620	29,464	116,084	1,385,083	403,763	38,190	22,015	1,116,082	3,081,217
8/20	86,620	29,464	116,084	1,385,083	404,878	41,484	22,217	1,123,162	3,092,908
8/21	86,620	29,464	116,084	1,385,083	430,685	46,136	22,217	1,143,217	3,143,422
8/22	86,620	29,464	116,084	1,385,083	457,196	54,804	22,217	1,167,239	3,202,623
8/23	86,620	29,464	116,084	1,385,083	464,227	60,112	22,217	1,181,386	3,229,109
8/24	86,620	29,464	116,084	1,385,083	469,980	64,403	22,217	1,192,426	3,250,193
8/25	86,620	29,464	116,084	1,385,083	477,386	70,317	22,217	1,202,286	3,273,373
8/26	86,620	29,464	116,084	1,385,083	482,669	75,317	22,217	1,208,150	3,289,520
8/27	86,620	29,464	116,084	1,385,083	499,298	78,006	22,292	1,217,172	3,317,935
8/28	86,620	29,464	116,084	1,385,083	521,766	81,558	22,421	1,229,302	3,356,214
8/29	86,620	29,464	116,084	1,385,083	535,047	85,654	22,421	1,241,081	3,385,370
8/30	86,620	29,464	116,084	1,385,083	542,299	93,148	22,421	1,249,612	3,408,647
8/31	86,620	29,464	116,084	1,385,083	546,894	97,587	22,421	1,254,634	3,422,703

[a] Chinook salmon >655 mm.

[b] Chinook salmon ≤655 mm.

[c] Includes sockeye salmon, cisco, whitefish, sheefish, burbot, longnose sucker, Dolly Varden, and northern pike.

APPENDIX F: PILOT STATION SONAR FISH PASSAGE ESTIMATES BY SPECIES, 1995–2015

Appendix F1.–Passage estimates, by species, at the Pilot Station sonar project on the Yukon River, 1995–2015.

	Chinook			Chum						
Year [a]	Large [b]	Small [c]	Total	Summer	Fall [d]	Total	Coho [d]	Pink	Other [e]	Total
2015	86,620	29,464	116,084	1,385,083	546,894	1,931,977	97,587	22,421	1,254,634	3,422,703
2014	103,613	34,372	137,985	1,924,425	650,808	2,575,233	247,047	513,599	964,350	4,438,214
2013	105,433	11,726	117,159	2,747,218	716,727	3,463,945	84,795	4,624	1,029,900	4,700,423
2012	90,936	15,790	106,726	2,130,404	682,510	2,812,914	106,782	352,518	678,382	4,057,322
2011	87,090	19,937	107,027	1,778,870	698,762	2,477,632	118,453	5,934	637,062	3,346,108
2010	95,913	17,497	113,410	1,327,581	350,981	1,678,562	142,149	651,128	761,800	3,347,049
2009 [f]	92,648	30,342	122,990	1,285,437	240,449	1,525,866	205,278	16,380	677,860	2,548,394
2008	106,708	23,935	130,643	1,665,667	615,127	2,280,794	135,570	558,050	585,303	3,690,360
2007	90,184	35,369	125,553	1,726,885	684,011	2,410,896	173,289	71,699	1,085,316	3,866,753
2006	145,553	23,850	169,403	3,767,044	790,563	4,557,607	131,919	115,624	875,899	5,850,452
2005 [g]	142,007	17,434	159,441	2,439,616	1,813,589	4,253,205	184,718	37,932	593,248	5,228,544
2004	110,236	46,370	156,606	1,357,826	594,060	1,951,886	188,350	243,375	637,257	3,177,474
2003	245,037	23,500	268,537	1,168,518	889,778	2,058,296	269,081	4,656	502,878	3,103,448
2002	92,584	30,629	123,213	1,088,463	326,858	1,415,321	122,566	64,891	557,779	2,283,770
2001 [f]	85,511	13,892	99,403	441,450	376,182	817,632	137,769	665	353,431	1,408,900
2000	39,233	5,195	44,428	456,271	247,935	704,206	175,421	35,501	361,222	1,320,778
1999	127,809	16,914	144,723	973,708	379,493	1,353,201	62,521	1,801	465,515	2,027,761
1998	71,177	16,675	87,852	826,385	372,927	1,199,312	136,906	66,751	277,566	1,768,387
1997 [h]	118,121	77,526	195,647	1,415,641	506,621	1,922,262	104,343	2,379	621,857	2,846,488
1995	130,271	32,674	169,945	3,556,445	1,053,245	4,609,690	101,806	24,604	1,011,855	5,917,900

[a] Estimates for all years were generated with the most current apportionment model and may differ from earlier estimates.

[b] Chinook salmon >655 mm.

[c] Chinook salmon ≤655 mm.

[d] This estimates may not include the entire run. However, in 2008 through 2014, operations were extended to September 7 instead of the usual end date of August 31.

[e] Includes sockeye salmon, cisco, whitefish, sheefish, burbot, suckers, Dolly Varden and northern pike.

[f] High water levels were experienced at Pilot Station therefore, passage estimates are considered conservative.

[g] Estimates include extrapolations for the dates June 10 to June 18 to account for the time before the DIDSON was deployed.

[h] The Pilot Station sonar project did not operate at full capacity in 1996 and there are no passage estimates for this year.